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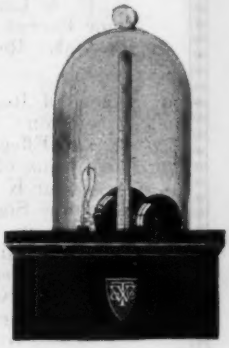

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Discussion of all papers is invited

Vol. 28 SEPTEMBER, 1936 No. 9

WHAT'S AHEAD FOR A. W. W. A.

By F. A. Barbour

(*President, American Water Works Association, Boston, Mass.*)

The answer to the question in the title assigned to me depends on the realization of the opportunity open to the Association to become a vigorous, well coördinated service agency for the entire water works field—not only technically but in activities looking toward improved public relations and the betterment of the economic and social status of water works personnel.

The Association in the 55 years of its existence has made good progress toward its constitutional objectives of advancing the knowledge of design, construction, operation and maintenance of water works. Outstanding milestones in this progress are the change in 1914 from a one-convention, one-volume per year organization to the formation of Sections and the starting of the Journal, the appointment in 1920 of the Standardization Council,—the forerunner of the present Water Works Practice Committee, the preparation and publication of the Manual of Water Works Practice in 1914–28, and the establishment in 1924 of the Technical Divisions.

The Sections, now numbering twenty-one, constitute beyond any question the most important asset of the Association in point of possible future service to the general membership. The Journal—starting as a quarterly, and since 1920 issued monthly, has as a re-

sult of the efforts of the Chairmen of the Publication Committee and of the Editor come to be recognized as the leading publication in the water works field. The Water Works Practice Committee, through the self-sacrificing service of its past and present Chairman and its various sub-committees, has done valuable investigational and standardization work.

What then is the present status of the Association's activities? What more must be done in order that the Association may become a real service agency to all branches of the water works industry?

In the first place, it is necessary, in my opinion, to recognize the necessity of more continuous directive control of activities by the Headquarters Staff. Past progress has been dependent on voluntary service, and there can be no doubt as to the magnitude of such service still available, but—in order to become a working organization, capable of realizing the opportunity open to the Association, an executive staff must be developed which will quarantee a continuity of action not possible by voluntary service, particularly under present and near future economic conditions. The detailed direction and stimulation of research and investigational work imposes too great a burden on the Chairman of the Water Works Practice Committee, and the annual intensive drive for a Convention program too great a load on the Chairman of the Publication Committee.

There has not been developed and there cannot be developed by voluntary effort the coördination of headquarters and Sectional programs and activities necesary to the full realization of the possible value of the Sections to the membership.

To capitalize the existing unity of local interest and to facilitate coöperation with water works schools, operators conferences, registration, civil service, and other movements looking toward the raising of the standard of service available, the formation of Local Sections in all states, as rapidly as may be feasible, should be promoted.

To make the Association of greater technical value in the water works field, its headquarters should, by the assembling of basic data and operating statistics, become the recognized center of such information. More research and investigational work should be undertaken, and the membershp should be carefully scrutinized in order to bring new men into active committee service. There are problems of standardization demanding investigation—such, for instance, as the development of more sensitive meters—the solution of which in economic return would well justify the effort.

The present edition of the Manual of Water Works Practice is rapidly approaching exhaustion. The original intent was to revise and issue new editions at reasonably frequent intervals, and thus to develop a manual of real value in the water works field.

There are signs that the stimulating effort of the undertaking of the first edition of the Manual and the establishment of the Water Works Practice Committee is gradually losing impetus.

Equally important as technical progress in determining future usefulness of the Association is a recognition of its obligation to add to its constitutional objectives the improvement of municipal service conditions and the betterment of the economic and social status of its operating membership.

The clear field of the Association is municipal water supply, and the membership is largely made up of men engaged in service activities in their various communities, whose tenure of office is so frequently determined by political exigency rather than competency as to nullify any incentive to improve their technical capacity. In this condition largely lies the explanation of the fact that with some 12,000 water systems in this country, less than 7½ percent are represented in the Association and less than one quarter of our active members have been members for more than five years.

In any program for the betterment of service conditions an obvious first step is contact and coöperation with the group of organizations having as their primary objective the improvement of municipal administrative practice, which, with headquarters in Chicago, have provided for coördination of their activities through the so-called Public Administration Clearing House, and which now constitute the best organized effort to raise the standard of municipal service.

In such expansion of Association activities into the field of public relations, methods and procedure must be formulated from headquarters, but the result will largely depend on localized effort and the real work must be done through the Sections. The obvious objective is education of the average citizen to a better understanding of the importance of competent experienced supervision of municipal utilities, and particularly of that most vital of all utilities—the water works system.

Publicity which will make the consumer and tax-payer conscious of the plant and operating personnel necessary for the furnishing to him of an uninterrupted supply of safe and acceptable water is what is needed. Research, papers and discussions are all necessary to

advancing technical knowledge, but the creation of a public opinion which will provide opportunity for the effective use of such advancing knowledge by demanding the retaining in office of competent men is the greatest need in the water works field at the present time.

The establishment of better public relations is a problem of live interest to other technical organizations. What the American Water Works Association can do toward its solution largely depends on available income, and this in turn on the number of contributing members. Evidence that the Association is starting to do its part toward the improvement of municipal service conditions will constitute an appealing argument to many water works men who now hesitate to join the Association because of probably short tenure of office and inadequate compensation.

Obviously, as a base for the expansion of Association activities, a well planned membership expansion program should be developed and continuously maintained through Section activities under the direction of the headquarters staff. A complete census of all eligible water works personnel should be developed and kept up to date through contacts with State Departments of Health and other agencies, and the benefits to be obtained by joining the Association should be brought home to all service men by literature sent out from headquarters and by personal contacts of member allocated by the Section officers.

Publicity can start simply by taking advantage of every opportunity to inform the consumer of the plant from which he obtains his supply of water and the men responsible for the operation of the plant. Photographs of all service men contributing to Convention or Sectional meeting programs should be sent to their home papers with popular digests of their contribution. Moving pictures of the plant which furnishes the water—as have been developed by the Indianapolis Water Company, the City of Akron, and other municipalities for presentation to various local organizations—provide the best possible means of educating the local public to the fact that the furnishing of a safe and acceptable supply requires technical capacity and experience.

What's ahead for the A. W. W. A.? In the above brief statement, certain steps toward the development of a continuously functioning central agency for the water works industry have been outlined and may be summarized as follows:

1. The development of the headquarters staff necessary for vigorous, continuous directive control of Association activities.
2. Coördination of headquarters and Sectional programs.
3. Encouragement of the formation of Sections in all states to facilitate coördination with water works schools and operators conferences.
4. The systematic collection of water works statistics to the end that the Association may become the central source of information for all branches of the water works field.
5. Invigoration of research and standardization activities.
6. Recognition of an obligation to coöperate in the betterment of municipal service conditions, and to this end to contact with other organizations having the same objective.
7. The maintenance of a continuous membership expansion program.

EXPERIENCE WITH AUTOMATIC CONTROL EQUIPMENT AT PUMPING PLANTS

By H. A. Harris, Jr.

(Operating Engineer, California Water Service Company, San Francisco, Calif.)

The trend in the past twenty years to supersede steam driven pumping equipment with electrically driven equipment is largely responsible for the development of automatic control.

Our Company operates 140 pump stations in 21 water systems in California. These stations each contain from one to fifteen pumping units, the total number of pumping units being 267. Of these 182 are production units, that is, connected directly to the source of supply, and 85 are booster units.

All regular operating plants are electric motor driven, the three steam plants on the system are maintained only as standby equipment.

The general type of many of our California systems makes automatic control essential to economic operation. The usual system supplied entirely by wells consists of various well stations scattered throughout the area served. Systems of this type have developed in this manner for these reasons: first, the wide spacing of wells results in minimum interference between them; second, such spacing reduces the size of feeder mains required to distribute water.

In the past a system of the above type was operated by having attendants continually on duty at two or three key stations, and having also circulating operators to operate the balance of the stations. Whenever there was a failure of electric power the traveling operators had to visit all stations as rapidly as possible and restart all pumps.

With the perfection of the automatic reduced voltage starting compensator these were installed in place of the manual compensators; the pumps then restarted automatically when power came on after a power failure.

In some cases where several pump stations were located fairly

close together, it was decided to extend control wiring from one central station to several outlying stations and start and stop these outlying stations from the control station in accordance with demands.

TYPES OF CONTROL

We operate three general type of automatic control—(1) float switch, (2) pressure or hydrostatic control and (3) electric time clock. These three are combined in various manners.

The best way to illustrate our various types of automatic control is to describe certain of our plants and their operation.

Float switch control

In nearly all cases where the pumps are near to a storage reservoir or a tank, we install a float switch in the reservoir and start and stop the pumps by means of the water level in the tank or reservoir.

At Bakersfield we serve a population of 35,000 and have a maximum daily consumption of 18 m.g. We operate 29 pumping plants with two traveling pump operators. Twenty-two of the pumping plants are automatically controlled. Most of these are controlled by a pressure governor.

The governor has contacts which are operated by pressure. The pressure at which it is desired to have the pump start is set and when the pressure drops to that point contact is made in the governor to the control wiring on the starting contactor and the motor is started. The pump then operates until the pressure reaches the high setting on the governor, at which point the governor circuit is disconnected and the motor stops. Any form of relay which controls equipment as a function of pressure must be combined with some form of surge protection. We accomplish this by the installation of an air chamber in the pipe leading from the discharge main to the pressure governor. The entrance to the chamber is through a small orifice so that it takes several minutes for a change in the system pressure to reach the governor.

In a system with a great many pumping units the governors are given various settings so they will cause the pumps to come on as they are required. The most efficient units are set to come on first and go off last, with other units coming on the line to meet maximum loads. A few plants used only for a few hours a day on peak demands are manually controlled. In this type of system it is necessary to

have altitude valves on storage tanks and reservoirs in order to prevent them from overflowing, and to release storage when required. The altitude valve is set to close at a full tank and reopen with a small drop in pressure on the system side of the valve.

At our Mallard pump station on the Sacramento River in Contra Costa County, we have three pumping units with a combined daily capacity of 25½ m.g. The control board is so wired that upon pressing the "start" button the units will start successively, with a definite time interval between the starting of each unit. This reduces the starting current required. The order of starting can be changed in any manner desired. In event of power failure, upon resumption of service the pumps will restart in the order previously set. The 36-inch discharge line from this plant has a 24-inch Larner-Johnson check valve which opens and closes slowly with starting and stopping of the pumps. A surge chamber of special design is located on the line just outside the pump station. This surge chamber is designed so that it is closed when the pumps are operating and open when the pumps are stopped. The surge chamber is built with two compartments. The inner compartment is connected to the pipe line and the outer compartment to a waste line. There is a valve in the inner compartment which seats at the top of this compartment. A locking device holds the valve open when the pumps are stopped. When the pumps are started a solenoid in the motor circuit is energized and releases the locking lever on the valve. The valve then rises to its seat at the top, and is held there by the operating water pressure. With the stopping of the pumps the solenoid is de-energized and drops the locking lever into place, and the valve drops due to its weight and decrease of water pressure. When the valve drops into full open position the locking lever catches, and holds the valve locked open until the pumps start again. The opening of the valve allows the surge to overflow the inner chamber into the outer and thence into the waste line provided.

Another very interesting automatic control is located in the Contra Costa District. In 1931 we constructed what is known as our San Ramon Valley line. This is 15 miles in length with two booster lifts, with storage tanks at the upper end of each lift. Two pumps are located in our Galindo Pump Station taking suction from a 400,000 gallon collecting basin. The pumps operate against a static head of 210 feet, and combined static and friction head of 250 feet. The second lift pumps take suction from a line out of

the first storage tank, and operate against a static head of 270 feet and a combined static and friction head of 320 feet.

The control equipment on each of these lifts is the same and I shall describe one. On the switchboard is located a pressure governor and a magnetic contactor with incidental wiring and push buttons and an electric time relay. On the pump discharge line is a Larner-Johnson check valve, and on a tee taking off the discharge line is a Larner-Johnson surge suppressor. At the storage tank is located an altitude valve of the type actuated by direct head from the tank.

The operation of this plant is then as follows: The pressure governor is set to make contact at a pressure corresponding to a drop of about 12 or 15 feet in the tank water level. As the pumps start the check valve opens slowly, and the water moves up the seven miles of pipe line to the tank. Upon the filling of the tank the altitude valve closes, thus causing a pressure rise in the line and at the pump station. This pressure rise causes the pressure governor to break the contact, thus stopping the pumps. At the same time the check valve begins to close due to pressure differential, and the surge valve opens, due to pressure drop. Thus the return flow goes out through the surge valve and into the line on the low side of the booster pump. The check valve closes in a period of about a minute, and the surge valve in from one to two and one-half minutes. The pressure rise is only about 20 pounds above normal pumping pressure.

As an added safety feature, in case the pressure control fails to start the pumps within a two-hour period after shut-down, a time relay will start them automatically and the operation will proceed as before.

Some difficulty was experienced in the beginning to get all parts functioning properly, particularly the check and surge valves; however, for the past five years these plants have been operating very successfully with a minimum of attendance.

An entirely different type of control was installed to operate three pumping plants in one of the beach cities. Four pumping units pump into a distribution system upon which floats a 400,000 gallon reservoir. A $\frac{3}{4}$-inch pipe line was laid from the reservoir to the pump stations. Three of the units located reasonably close together are controlled by one board, while the fourth has its own board. The hydrostatic pressure is conducted to a

mercury chamber in which there are a series of contacts. The relays and circuits are so connected, that with the water level in the reservoir falling, when the first contact is reached the first unit starts; when the second contact is reached a second larger unit starts and the first unit stops; the third contact starts the first and third units and stops the second unit; the fourth contact stops unit one and starts unit two while unit three continues to operate; the fifth contact starts unit one again with units two and three remaining on. This hookup provides automatically for five different rates of pumping with only three pumps. With a rising water level in the reservoir, the pumps go off in an order opposite to the one in which they were started with the falling water level.

Pressure or hydrostatic control

We have a great many units controlled by float switches on tanks and reservoirs. This is a very positive method of control, but proves somewhat expensive in first cost if the distance from reservoirs to pump station is much over one mile.

About three years ago we installed a booster station at Petaluma to take care of an extensive high level area. We were obliged to keep down first cost, and therefore had to use a small tank, which we had available, for storage. The capacity of the tank was only four thousand gallons and the effective height only six feet. The booster station was located at the low service reservoir about six thousand feet from the high level tank. A survey showed that it would be very expensive to construct a float switch control line, due to the fact that the only available pole location was taken up by power, telegraph and telephone lines. We were quite skeptical of the ability of a pressure control system to operate successfully but decided to try it. An altitude valve was installed at the tank, and a pressure governor at the pump station. The governor was set to start the pump upon a drop of about three pounds below full tank pressure, and stop at a pressure several pounds above full tank pressure. When the tank is filled the altitude valve closes, thus causing a rise in pressure sufficient to break the governor circuit and stop the pump. Upon a sufficient drop in pressure the governor closes and restarts the pump. The reason for doubt about the successful operation was, that changing demands on the pipe line between the pump and tank would cause a variation in pressure at the tank for a fixed pressure at the pump, and might in some instances cause the

tank to empty entirely before the pump would start. However, the operation of this plant has been entirely successful, much to our gratification.

We have a number of installations where 6 or 8 well pumps discharge into a small collection tank, and a booster pump delivers the water to the central distribution reservoir. The usual installation in this case is to make the booster slightly larger in capacity than the combined well pumps. The traveling operator starts the required number of well pumps, and the booster is float controlled by a float in the collecting tank which starts the booster when the tank is nearly full and stops it before the tank is emptied.

We have several wells where aeration of the water is necessary. The installation in these cases consists of a well pump, a cascade or other type aerator, and a small collecting basin. The operation is as follows: The basin is full at the beginning of the operation; the booster pump is started, by reason of a drop in the distribution system pressure to the point set for starting on the pressure governor. When the water level in the basin reaches a point about two feet from the bottom, the float switch closes and starts the well pump, the well pump continues to run until the water reaches a point a few inches below the top of the basin, at which point the float switch opens and stops the well pump. A second float switch is set to stop the booster pump just prior to the basin becoming empty and to start the booster just before the basin overflows. If the well pump has a capacity slightly in excess of the booster, the well pump will stop and start automatically while the booster continues to run on its pressure control. However, if due to a change in conditions the booster should have a capacity in excess of the well pump, the booster would be stopped by the second float switch, and restarted by this switch in case the first switch failed to cut off the well pump when it should.

At San Mateo we have a well pump delivering water into a 100,000 gallon collection tank from which a booster pump takes water and delivers it into the system. The booster pump is normally controlled by a pressure governor on the distribution system pressure. Three float switches are installed in the collection tank.

A complete cycle of operation is as follows: About midnight the pressure in the distribution system will rise sufficiently to stop the booster pump. The well pump runs continuously and about 4:00 or 5:00 A.M. the tank fills to a point about 8 inches from the top; the

first float switch will then start the booster pump which continues to operate until the water is lowered to a point 16 inches below the top. If the booster should fail to operate, or should pump less water than the well pump is delivering, the second float switch would stop the well pump when the water level reached a point 2 inches below the overflow, and would start it again when the water level had fallen 12 inches. This procedure insures the tank being full of water in the morning when the system requires water, and also utilizes the well to its maximum capacity.

The booster will start about 7:00 or 8:00 o'clock in the morning, due to drop in system pressure, and continues to operate until rise in system pressure stops it. If through a break in the distribution system or failure of the well pump the booster should empty the tank, the third float switch would stop the booster and would not allow it to restart until there was 12 inches of water in the tank above the booster outlet.

To summarize the operation of this plant: The pressure governor operates the booster pump when water is most needed in the system; the first float switch operates the booster to utilize the full capacity of the well and tank, the second float switch keeps the well pump operating and prevents the tank from overflowing, and the third float switch prevents the booster from running dry.

The well pump delivers continuously about 150 g.p.m. and the booster supplies 300 to 400 g.p.m. during peak demands lasting about three hours.

At Redding we have a pump station on the Sacramento River pumping river water to a reservoir about a mile and a half away. The pumps are controlled by a circuit connected to fixed metal disc contacts in the reservoir. When the water falls to the level of the lower contact the pump is started, and when it rises to the upper contacts point the circuit is broken and the pump stopped. An alum machine and a chlorinator located at this plant are stopped and started by the control circuit on the main pump motors.

At Marysville are two large triplex reciprocating pumps driven by slow speed motors which pump water to a storage tank located at the top of a four story building. These pumps were manually operated for over forty years, and considerable doubt was felt that they could be successfully operated automatically. However, about six years ago a float switch control was installed from the tank to the pump station, and each of these triplex units is operated by a

separate float switch. A deep well turbine pump located over a mile away is also controlled by a third float switch on this same tank. These units can be set to come on in any desired order by changing the float switch contact settings.

Electric time clock control

We have just recently installed a somewhat novel installation at San Carlos. This is a small plant with an average daily demand of 80,000 gallons. About 90 percent of the supply comes from the San Francisco Water Department transmission line. A recent reduction of the pressure carried on this line made necessary the installation of a booster pump. We already had 100,000 gallons in storage capacity which was used to serve the low-level system. A first high-level area was previously served by San Francisco pressure directly without storage, and a second high-level section was served by the same pressure but had 40,000 gallons of storage. Due to high cost of real estate and the small quantities of water handled, our studies showed the most economical installation would be a booster station with a single unit which could pump to all three locations. An air pressure tank was installed on the same property as the low-level tanks, to serve the first high area. A check valve was installed on the line to this area. A check valve was also installed on the line leading to the second high-level storage. Two pressure governors were installed at the pump station, one connected to the air pressure tank line and one to the low level line. (The second high-level area is on this same line.) Action of either pressure governor will start the pump, but only when both are in off position will the pump be stopped. Due to high friction losses in line to low level tanks, we expect that sufficient water will go to the high-level tanks on second high area while low-level tanks are filling.

A time relay is also being installed on the control circuit so that the pump can be set to run during definite time intervals if such should prove advisable. This clock has two "on" points and two "off" points so that it can be set for two complete cycles of operation each day. When the clock is cut into the motor control circuit, the pressure governors cannot stop the pump while it is running during the set time intervals, but the governors control during the time between an "off" position and an "on" position on the time relay. This installation could be improved by the use of a float valve to

shut off the low-level tanks, but due to a considerable quantity of old light weight steel casing in the distribution system, some concern was felt over installing such a valve, although this may be done later. Only experience in handling this station will show the necessary settings on pressure governors and time relay to give best operation.

We have quite a number of booster pumps operating in connection with air pressure tanks serving individual high-level areas of 25 to 400 consumers. All such pumps are controlled by the pressure in the air pressure tank. The usual range is about a 30 or 40 pound differential between "on" and "off." This type of installation has proved most satisfactory for this type of service.

At Redondo Beach we installed a booster station to pump from the low-level transmission main to a 50,000 gallon high-level tank. This pump was originally controlled by a pressure governor connected to the discharge main leading to the tank. Due to this line being small and the friction loss high, and having varying demands off the line between tank and pump, difficulty was encountered. This condition caused a wide variation in the pressure at the pump station for a given water elevation in the tank, and the tank was either overflowing or going empty. The most economical cure in this particular instance was to lay a $\frac{3}{4}$-inch line from the tank to the pump (a distance of about 2000 feet), and connect the pressure governor directly to this hydrostatic line, thus eliminating the effect of friction. This installation has worked very well since this change was made. We have another installation very similar to this but utilizing a mercuoid switch instead of a pressure governor.

We have just completed the installation of a complete automatic control at two of our East Los Angeles plants. We have one well pump at a station which pumps to a receiving basin at another station. At the latter station is also a well pump discharging into the same basin. There is a float switch control on each pump. The pumps are started and stopped at set water level points in the basin. Each pump starts and stops at a different point. A booster pump located in the same station as the receiving basin is stopped and started by means of a float switch on a steel stand pipe located about 1800 feet away. This standpipe is in balance with an elevated tank located almost a mile away. The water level in the elevated tank is controlled with an altitude valve, and for additional safety there is an overflow on the standpipe. There are six pump stations in addition to the two just mentioned pumping into the distribution

system served by these same two storage tanks. Four are controlled by pressure, and two with time clocks which are set to operate them during time of peak demands.

The complete cost of providing automatic control in the two plants above was $1900 and the annual saving $4000. This well illustrates the economies which are possible. On well pumps controlled by float switch or time clock we provide definite time relays which prevent the pump from starting within several minutes after stopping. This is to insure that they will not be started while spinning in reverse. On those controlled by pressure governors sufficient time lag is provided by the air chamber previously mentioned.

SUMMARY

To give a general idea of the extent of automatic control on our system, we have 104 plants automatically controlled and 36 manually controlled. Of these 36 about 20 are used only as stand-by or for peak loads.

On our entire system we have only 8 pump stations where we keep a full shift of operators on duty. At 3 of these filter and treatment plants are located which require the continuous services of an attendant. A fourth is the Mallard Pump Station on the Sacramento River which is operated about four or five months out of the year. Of the remaining four we have tentative plans to change one to automatic control.

Our success in automatic control is due in no small amount to the development of very dependable electrical equipment in the line of magnetic contactors, relays, time clocks, pressure governors, float switches, time delay switches, etc. Another fair share of credit goes to makers of altitude and regulating valves. A small share of the credit we take for ourselves in proper design and adaptation of the above equipment to our specific problems.

We do have occasional failures in our automatic control, and certain installations have not operated as ideally as anticipated; but on the whole all of this equipment goes on operating day after day with no attention other than a reasonable amount of inspection and maintenance.

The best test of our success in automatic operation is the fact that we operate 267 pumping units in 140 pump stations, located in 21 separate water systems, with a combined annual production of

14.2 billion gallons, and the annual expense for pumping labor is $62,000. This represents a labor cost of $4.35 per MG, or $440 for each pump station operated. The total cost of maintenance of pumping equipment, including all automatic control, amounts to $7500 annually, or about $28 per pumping unit. This annual maintenance figure is approximately three-quarters of one percent of the capital invested in electric power pumping equipment.

MODERN AIR CONDITIONING—WHAT IT MEANS TO THE WATER UTILITY[1]

By L. L. Lewis and L. H. Polderman

(The Carrier Engineering Corporation, Inc., Newark, N. J.)

It is good that interest is leading to a consideration of this problem, for, while it will offer welcome opportunities to many, it will require careful planning for the future by some. This planning will require an examination of the adequacy of supply, the capacity of pumping equipment to meet maximum demand, and the capacity of distributing systems with reference to the focal points of that demand.

While it may be possible that air conditioning has but recently become of interest to you, it is by no means a novelty. The industry is some thirty years old, having started with a small group of engineers in Buffalo. It really got under way with the disclosure of the psychrometric chart before the American Society of Mechanical Engineers in 1911 by Willis H. Carrier, who headed this small band of pioneers. During the first twenty years, application was limited almost entirely to industrial plants and, hence, few people knew of it. About ten years ago, its application began to spread rapidly to theatres, department stores, restaurants, and other buildings in which the public gather.

This second phase of development brought improvements in equipment and price reductions, and greatly broadened the market. The accomplishments of the pioneers in the development of air conditioning have been truly remarkable. Unitary equipment, which can be manufactured by production methods, has brought the price level of small installations within reach of the individual who is interested solely in his comfort, or of the commercial establishment which makes an investment in air conditioning for the dividends it pays. Contrasting examples of this remarkable development are shown in the accompanying illustrations.

For example, only a few years ago, Jones would have paid $10,000 for air conditioning his corner drug store, and would have been com-

[1] See also Journal, March, 1936, pages 318–329.

pelled to hire two licensed refrigerating engineers to operate his plant. Today, Jones can buy better equipment for less than $3,000 and can operate it himself with push buttons or thermostatic controls, placed in any convenient location in his store. Its initial cost and its operating cost have been reduced to a point which makes it a good investment for Jones.

ELEMENTS OF AIR CONDITIONING

The term "air conditioning" has been so loosely applied, as public interest in air conditioning has grown, that it is in order to define it. Carrier's conception of true air conditioning is that it should:

1. Control temperature by:
   a. Heating in winter.
   b. Cooling in summer.
2. Control humidity by:
   a. Adding moisture in winter.
   b. Subtracting moisture in summer.
3. Supply ample ventilation to:
   a. Dilute odors.
   b. Dilute smoke.
4. Evenly distribute by causing a controlled circulation of properly tempered air which will:
   a. Give "life" to the air.
   b. Produce effective, mild distribution.
5. Clease the air by removing:
   a. Dirt.
   b. Minimizing odors.

Before it can be said that a place is really air conditioned, therefore, that place must contain air which is as nearly perfect as to moisture content, temperature, purity, as it is humanly possible for man-made machines to make it. Also, air must be distributed in such a way that draughts will be eliminated, while, at the same time, the distribution system must be designed to minimize noise. Just to cool, just to heat, just to wash the air in a room by artificial means—to perform any one or all three of these functions is not true air conditioning. Only when the air in that room is controlled in the five ways mentioned on the preceding page, can it be said that that room or place is completely air conditioned.

Not all installations can be designed to meet the practical ideal of true or complete air conditioning due to limitations of cost or

because of circumstances which do not require all the functions that are a part of such an air conditioning system. It is important, in such cases, to realize that ideal performance cannot be expected from systems that do not accomplish 100 percent air conditioning.

Lack of a proper understanding of true air conditioning has led to misunderstanding by many and opened the gate to inaccurate representation of equipment, so that apparatus that performs but a few of the functions of air conditioning is sometimes said to be "complete" when, in fact, it may only humidify and heat, cool without dehumdifying, ventilate only, or filter the air without otherwise treating or conditioning it.

Without reference to those functions of relatively less importance, it may be descriptively divided into:

1. Summer air conditioning, which cools and dehumidifies.
2. Winter air conditioning which humidifies and heats.
3. Complete, or true, air conditioning, which cools, heats, dehumidifies and humidifies according to the requirements.

The equipment required to control the air in the room for complete or summer air conditioning can be divided into two groups, according to function:

1. Air motion and treating equipment.
2. Refrigerating equipment.

The function of the first is that of conditioning the air, which is then introduced into the room in such a manner as to meet the requirements for air conditioning. The function of the second is to extract heat from the air and thereby perform exactly the reverse function of the boiler, which supplies a means of adding heat to the air.

It is the refrigerating equipment which performs this second function that imposes the main requirement for water. Some water is required for winter conditioning, but the volume required is so small that it need not be considered.

The amount of heat which has to be removed for true air conditioning is widely variable, even for establishments of apparently equal requirements. The rays of the sun heat the building structure if and where they strike it, being reflected and absorbed in proportions varying with the nature of the external surface, or pass through glass with only a slight filtering effect to impinge in almost full intensity upon any objects within its path. The radiant heat so absorbed by the structure flows to the interior, while, on the shaded

sides, heat from the warmer outside air flows through the building structure to the interior.

Thus, of two spaces of identical size and shape, not only the extent and character of exposure, but also the thickness and nature of building material will vary the inflow of heat over a very considerable range. Some conditioned spaces have no external exposure—others have an unprotected exposure on all sides.

In addition to these two sources of heat which, in air conditioning parlance, are known as sunlight and transmission gains, there are numerous other sources of heat. Among them are human beings, each of which must be considered a heater, giving off heat in both its sensible and latent form or, with freedom of expression, dry and moist heat. Every light, every electrical device, every coffee urn, is a heater, all giving off dry heat and some both dry and moist heat.

The heat from each of these sources and others not mentioned can be accurately estimated and is ordinarily designated as "heat gain." It must be absorbed by the air which is conditioned by the air motion equipment. From the air so treated, exactly the same amount of heat plus the excess heat in whatever volume is drawn from out of doors for ventilation must be extracted. This heat is ordinarily designated as "total heat."

This "total heat" must be removed by the refrigerating machine, and the problem centers upon the water requirements of the refrigerating machine.

THE REFRIGERATING MACHINE

In its simplest elements, the commonly used compression machine consists of three parts: The cooler, in which the refrigerant absorbs heat at a low temperature; the compressor, which raises the pressure of the refrigerant so that the heat received in the cooler may be removed at a relatively high temperature; and the condenser, from which the heat carried from the cooler by the refrigerant is finally removed.

Numerous types of refrigerating machines are available utilizing a wide variety of refrigerants—ranging from water to liquid or solid chemicals. A jet of steam may, for example, serve as a compressor or gas pump. Many railroad cars are "cooled with steam." Chemicals or solutions having an affinity for water vapor may be utilized in such a manner as to produce refrigeration.

Some of these machines are gluttonous in their requirements for

water—others moderate. An excellent article, entitled "Spring in the Air," by Nathan N. Wolpert, dealing with their characteristics, appears in the November 11, November 27 and December 11 issues of "Water Works Engineering."

But, since a refrigerating machine—of whatever type—is only a heat pump, lifting heat from one level to a relatively higher one, the effluent heat must be carried away by some means.

This effluent heat usually is carried away wholly or partly by the water you furnish. Since the removal of heat is required during the late Spring, Summer and early Fall months, the demand for water is a seasonal one, reaching a maximum in mid-Summer and tapering off during the intermediate seasons.

The simplest way to get rid of this effluent heat is to buy water and pass it through the condenser to the sewer, changed in no manner other than its temperature is raised. If this were the only way to get rid of effluent heat, there might well be concern about the demand, for it could not be met with most existing plants.

But, in certain localities prices for water have been high and, in order to broaden the market for air conditioning equipment, those who have led in its development have sought and found means of greatly reducing the water requirements of air conditioning systems. Thus, economic forces have already caused the development of equipment for the purpose of reducing air conditioning sales resistance where water prices were high or where the threat of water shortage might restrict its use.

The first stage of this development (ante-dating air conditioning) was the cooling tower, that slatted structure which will be recognized as the architectural nightmare usually seen upon the roof of the local ice plant, but which, in some modern installations, has been completely harmonized architecturally.

This cooling tower is a means of heat disposal. The water passing through it is recirculated, being pumped through the condenser where it receives heat, and then through the cooling tower where it gives off this heat to the air.

Some of the water is carried away by the wind, some of it is lost by evaporation, and that which is lost must be replenished from mains. This loss is quite small, so that the use of this cooling tower for heat disposal cuts the demand for water to about 5 percent of what it would otherwise be.

The second stage was the development of the Carrier evaporative

condenser in which the functions of the condenser and the cooling tower are combined. The features of water conservation have been slightly improved and the space occupied by equipment greatly reduced. This piece of equipment may be placed upon the roof of a building and appear as a small rectangle or, if it is feasible to lead air to and from it through ducts, may be tucked away in one corner of the machinery room.

Since there is no windage loss from the evaporative condenser, it requires considerably less than 5 percent of the water which would otherwise be required.

Both the tower and the evaporative condenser are instruments for the conservation of water and are fully developed practically and commercially.

Single rooms of moderate size are now being cooled with equipment which requires no water at all. It is possible mechanically to do the same with larger equipment, but hardly practicable because of costliness and size.

WATER DEMAND

Therefore, a broad attack upon the problem of demands requires that an average be assumed for all types of refrigerating machines, as well as for varying economic balances between water temperatures and costs and power costs.

For a given power rate, cold water may throw the balance in favor of heat disposal entirely by water—warm water may do the opposite. Low power rates may favor conservation of water—high power rates the opposite. A combination of high's of water temperature and power cost operate strongly in favor of heat disposal by evaporation.

Cold water is favorable to those types which are large consumers of water, and to chemical adsorption and absorption types; warm water the reverse.

The complexity of these economic forces becomes apparent when it is realized that power for air conditioning may cost from less than 1 cent per kw-hour to more than 3 cents; that water may cost from 45 cents per 1000 cubic feet, up to $2.85—perhaps higher; that the temperature of the water coming from mains may range in summer from 56° to 85°; and that pocket-book limitations as to available capital may enforce the purchase of equipment which is above average in demand for water or power, or both.

Two gallons per minute per ton of refrigeration produced is considered a fair figure for this average.

Table 1 presents a fair cross-section of the water requirements of air conditioning in a typical city.

In table 1:

1. BTU per person per hour is the average "total heat" previously mentioned.

2. Maximum demand (gallons/hour) $= \frac{\text{BTU/person}}{12{,}000 \text{ BTU/ton}} \times 2$ g.p.m./ton $\times$ 60 minutes.

TABLE 1

Water requirements in gallons per person per cooling season of 120 days of various applications of air conditioning

(Compiled by Carrier Engineering Corporation)

	B.T.U. PER HOUR	MAXIMUM DEMAND	HOURS OF OPERATION PER SEASON	GALLONS PER SEASON AT MAXIMUM DEMAND RATE	LOAD FACTOR	WATER REQUIREMENTS
		gallons per hour			*percent*	*gallons per season*
Residence	4,000	40	2,900	116,000	30	34,800
Train	1,400	14	1,200	16,800	50	8,400
Office	4,700	47	1,200	56,400	40	22,500
Lunch room	1,600	16	900	14,400	50	7,200
Restaurant	2,000	20	1,200	24,000	60	14,500
Drug store	2,000	20	1,800	36,000	60	21,500
Theatre	1,000	10	1,500	15,000	30	4,500
Department store	1,600	16	1,200	19,200	60	11,500
Average	2,300			37,000		15,600

3. Hours per season and load factors are from experience.

The averages obtained in table 1 are carried forward into table 2, and expressed in more convenient form. Note that in the three sections of this table the gallons per person are given:

(a) Without the use of conserving equipment (a partly discontinued practice).

(b) With present practice.

(c) With full use of conserving equipment.

Note carefully that they are NOT PER CAPITA consumption,

but will become per capita consumption if and when a certain point of saturation, with respect to the installation of air conditioning, is reached.

It is possible to consider saturation from two points of view.

The first is absurd, but should be defined in contrast with the second which is useful in this study. The first is building saturation, that inconceivable stage at which every square foot of habitable space, occupied or unoccupied, from the most magnificent to the lowliest, is air conditioned.

The second, and usable saturation, is that stage at which air conditioned space is available for 100 percent of the population on which per capita water consumptions are based. In other words, each and every person making up the population could be in an air

TABLE 2

Average water requirements, gallons per person

(Compiled by Carrier Engineering Corporation)

	(1) IF NO EVAPORATIVE CONDENSERS OR COOLING TOWERS USED	(2) 1935 PRACTICE WHICH WAS 60 PERCENT USE OF EVAPORATIVE CONDENSERS AND COOLING TOWERS	(3) IF 100 PERCENT EVAPORATIVE CONDENSERS AND COOLING TOWERS USED
Per cooling season of 120 days	15,600	6,700	780
Maximum per day	300	130	15
Average per day per year of 365 days	43	18	2

conditioned space at the same time without overloading the equipment.

This is population saturation, and if and when it is reached the values given in table 2 will then become the per capita consumption of water due to air conditioning.

Therefore, if the present percentage of saturation can be determined, it will afford a factor[2] with which the PER PERSON RATES in table 2 can be converted into *per capita rates.*

[2] It is interesting to note in passing that super-saturation, with respect to population, can be reached. The average "total heat" per person (2300 BTU from table 1) is approximately five-sixths "environment heat" and one-sixth body heat. Therefore, if the inconceivable of building saturation is reached, the factor to be applied to the per person rates of table 2 would approach six.

The best data known to the authors was published in the April, 1936 issue of "Heating and Ventilating" (228 North LaSalle Street, Chicago). This issue tabulates the "Number and Size of Summer (i.e., using refrigeration) Air Conditioning Installations in Typical Cities During 1935 as Reported by Twenty-Seven Utilities to Whose Lines the Installations are Connected," as well as similar data prior to January 1, 1936. They include "Commercial, Industrial, Theatre and Recreational, Public and Institutional, and Residential" installations.

"Heating and Ventilating" states—"There is thus a definite record of nearly 300,000 horsepower and upward of 6,000 separate installations of summer air conditioning in buildings up to January 1, 1936. The actual total is still not known, but it is believed that the total number is around 8,000 and that the total horsepower exceeds 350,000."

The total horsepower of this connected load will be converted into the number of people air conditioned if it is multiplied by a factor "5", which is obtained as follows:

$$\frac{12{,}000}{2300} \times \frac{1}{1.15} \times 1.10 = 5$$

in which 12,000 is BTU per hour per ton of refrigeration, 2300 is average BTU per hour per person (table 1), 1.15 is average horsepower per ton including power for air motion, and 1.10 is a 10 percent allowance for other than motor-driven refrigeration.

This conversion is carried out in table 3, which shows that, up to and including December 31, 1935, air conditioning installations in twenty-five cities had reached 5.7 percent of population saturation. Therefore, based on 1935 practice in the installation of cooling towers and evaporative condensers, water consumption has reached 18 $\times$ 5.7 percent = 1.03 gallons per capita per day with a peak of 130 $\times$ 5.7 percent = 7.4 gallons per capita on the day of maximum demand.

In table 4 the number of people is shown for whom air conditioning was installed during the year 1935. Note well that in 33 cities, having a population of 27,006,000 people, the average rate of installation in 1935 was 1.27 percent, but varies over a very considerable range according to sales in different cities. Washington is far in the lead, due to large installations in the new Federal Buildings.

This 1935 factor applied to the per person rates in table 2 shows that the increments of increase in 1935 were 18 × 1.27 percent = 0.23 gallon per capita average daily use with a peak demand of 130 × 1.27 percent = 1.65 gallons per capita.

The increment for 1936 will be considerably greater than that for 1935—perhaps doubling, and continuing to double for several consecutive years before assuming a lower rate of increase. An increase of 1 percent of urban population saturation means a business of $75,000,000 to $100,000,000.

If sales of air conditioning double in 1936, 1937 and 1938, average daily use per capita will have reached 4 gallons, with a peak demand of 30 gallons per capita if 1935 practice in the use of conserving equipment is continued.

TABLE 3

Water consumption factors for air conditioning sold up to and including 1935 in 25 cities

Compiled by Carrier Engineering Corporation (Data on Air Conditioning Installations by Courtesy of "Heating & Ventilating")

YEAR	POPULATION	AIR CONDITIONING INSTALLED		PEOPLE FOR WHOM AIR CONDITIONING INSTALLED	
		Number of plants	Total horsepower	Number	Percent of population or water factor
Prior to 1933	25,181,000	1,161	162,125	810,000	3.2
1933	25,181,000	799	18,939	95,000	0.4
1934	25,181,000	1,568	46,874	235,000	0.9
1935	25,181,000	1,994	60,110	300,000	1.2
Up to and including 1935.....	25,181,000	5,522	288,048	1,440,000	5.7

If full use of conserving equipment be started on January 1, 1937, the respective figures would become 1.8 gallons and 13 gallons.

In all of the foregoing, average factors are used. They serve as examples for the use of a city factor for determining and predicting conditions in that particular locality and may be extended beyond 1938 if assumptions as to air conditioning sales are made.

Recorrecting factors should be applied in determining and predicting water requirements for particular localities or cities; since a

TABLE 4

Water consumption factors for air conditioning sold in 1935 in 33 cities

Compiled by Carrier Engineering Corporation (Data on Air Conditioning Installations by Courtesy of "Heating & Ventilating")

CITY	POPULATION	AIR CONDITIONING INSTALLED		PEOPLE FOR WHOM AIR CONDITIONING INSTALLED	
		Number of plants	Total horsepower	Number	Percent of population or water factor
Boston	1,700,000	54	1,851	9,300	0.6*
New York	6,900 000	283	11,031	55,000	0.8
Newark	565,000	21	508	2,500	0.4
Jersey City	317,000	7	34	170	0.1
Philadelphia	1,950,000	116	4,770	24,000	1.2
Baltimore	823,000	88	2,400	12,000	1.5
Washington	487,000	159	8,634	43,000	8.8
Rochester	329,000	28	668	3,300	1.0
Buffalo	620,000	46	656	3,300	0.5
Pittsburgh	832,000	95	1,423	7,100	0.8
Toledo	292,000	26	490	2,500	0.9
Detroit	1,760,000	90	4,395	22,000	1.3
Cincinnati	538,000	96	2,505	13,000	2.4
Indianapolis	367,000	27	1,330	6,700	1.8
Met. Chicago	3,460,000	317	5,461	27,000	0.8
Milwaukee	653,000	25	441	2,200	0.3
St. Louis	927,000	187	5,371	27,000	2.9
Minneapolis	484,000	35	459	2,300	0.5
St. Paul	276,000	19	149	750	0.1†
Denver	288,000	49	129	650	0.1†
Birmingham	278,000	22	951	4,800	1.7
Louisville	308,000	35	713	3,600	1.2
New Orleans	459,000	59	2,067	10,000	2.2
Dallas	273,000	64	1,206	6,000	2.2
Houston	295,000	46	2,466	12,000	4.1
Sub-total	25,181,000	1,994	60,108	300,170	1.2

* Note this is six-tenths of one percent.

† Anything less than one-tenth of one percent is given as 0.1.

TABLE 4—*Concluded*

CITY	POPULATION	AIR CONDITIONING INSTALLED		PEOPLE FOR WHOM AIR CONDITIONING INSTALLED	
		Number of plants	Total horsepower	Number	Percent of population or water factor
Miami	123,000	45	930	4,700	3.8
Akron	255,000	10	49	250	0.1†
Kansas City	405,000	116	3,721	19,000	4.7
Syracuse	217,000	6	211	1,000	0.5‡
Hartford	214,000	14	172	860	0.4‡
Scranton	214,000	10	138	700	0.3§
Richmond	183,000	74	1,867	9,300	5.1
Omaha	214,000	45	1,133	5,700	2.7‡
Sub-total	1,825,000	320	8,221	41,510	2.3
Total	27,006,000	2,314	68,329	341,680	1.27

‡ Eleven months only.
§ Ten months only.

rate of 2 gallons per minute per ton of refrigeration was used as a base rate, some recorrecting factors are:

(1) Where water temperature rises to 80° in summer, add to the following columns in table 2:

Column 1, 50%
Column 2, 20%
Column 3, 0

(2) Where water temperature does not exceed 75°, but costs as much as $1.50 per 1000 cubic feet and power may be had for less than 1.5 cents per KWH,—add to the following columns in table 2:

Column 1, 30%
Column 2, 12%
Column 3, 0

(3) Where water temperature runs 65° or lower, discount in the following columns in table 2:

Column 1, 40%
Column 2, 15%
Column 3, 0

The following conclusions seem to be warranted:

(1) That localities now without an adequate supply in seasons of drought should be singled out for 100 percent use of water conserving equipment, unless the assurance of an additional supply can be had.

(2) That in localities having an ample supply, pumping and filtering equipment may eventually have to be increased to meet the peak demand.

(3) That where supply and pumping equipment are ample, the concentration of air conditioning equipment in the business center may overtax mains at that focal point, or installations in the far reaches of residential districts may overtax smaller lines serving those districts.

DISCUSSION

J. S. STROHMEYER (*Distribution Engineer, Bureau of Water Supply, Baltimore, Md.*): Mr. Lewis and Mr. Polderman are to be congratulated for preparing a complete treatise on air-conditioning. As this industry continues to grow, it becomes of major interest to the water works profession because of the large quantities of water used. It is my intention to describe this interest as we of the Bureau of Water Supply of Baltimore consider it will affect the department.

Mr. Carrier conceives true air conditioning as fulfilling five major conditions, which are again subdivided. We are primarily interested in it as the control of temperature by cooling in summer, which is 1-b of his descriptive conditions. It is recognized that the demand for water from the Bureau's distribution system for air conditioning recently has shown a decided increase and it can be reasonably expected that this increase will continue as there is a tendency for all downtown stores, restaurants and places of public gathering to make such installations as a competitive measure. This is also the case for buildings of a similar class of occupancy in other sections. At present very few residences are so equipped.

The cost of electric power and water is reasonable in Baltimore; the highest temperature of the water during 1935 was 67°; therefore, these authors state that these conditions may throw the balance in favor of heat disposed by water. We find this to be the case, as there is no tendency to install equipment for the conservation of water.

Upon inquiry, we find that considering the capital cost of such

equipment, the cost of its operation for three or four months, the difficulty of finding a suitable location in the building, and the space occupied, it is economical to waste the water used for cooling.

To study specifically how air conditioning affects a water supply system, we have taken the quarterly meter consumption of four stores, located at the intersection of two streets in the downtown section of Baltimore. Three of these are department stores and the fourth a large drug store. During 1933 none of these stores was air conditioned and the combined consumptions were approximately 16,000,000 gallons for the summer quarter. Compared with the corresponding quarter of 1935, when all were air conditioned, the combined consumptions were in excess of 42,000,000 gallons. This difference in consumption of 26,000,000 gallons between the quarters can be fairly stated as caused by air conditioning. The quarter is 91 days, and omitting Sundays and holidays, the number of days on which this equipment would be operated is 77. The hours of operation per day are uncertain, but assuming 8 hours a day every working day, we have these four stores using 338,000 gallons of water a day at the rate of 1,014,000 g.p.d. These figures are averaged and do not indicate the consumption on the hottest day.

This average establishes for Baltimore the approximate use of water for 520 h.p. of air conditioning equipment. This compares surprisingly well with the average of table 2 where the average water requirements in gallons per person for 120 days is 15,600 gallons or 130 gallons per day. Using 520 h.p. equated at 2,600 people, the amount used by these four stores is 338,000 gallons during the average operative period and conditions for which this table is computed.

The 1936 Annual Report of the Consolidated Gas Electric Light & Power Company, a local utility, states (page 8) that the connected load of air conditioning and dehumidification was 7891 h.p. on December 31, 1935, an increase of 2400 h.p. during the year. This does not include any steam jet or stream engine installations. At the preceding rate of water use, this amount of horse power uses 5,187,000 gallons per day, and at maximum rate on account of the diversity of the time it is used of approximately 12,000,000 gallons. (Table 2,—300 gallons maximum per day.)

During the summer months the use of water by this industry increases the per capita daily consumption 5.7 gallons. As this increase in consumption occurs only during the summer months and

must be met then by the water system, it is erroneous to place it on a per capita per day extended over the year.

The actual increase in consumption between the summer months of 1933 and the same months of 1935 was 9,000,000 gallons a day. Although other elements contributed, unquestionably the use of water for air conditioning contributed to a large part of the increase.

Someone said that a municipal utility was unusual in that it tried to restrict use of its commodity as contrasted with private utilities, which try in all possible ways to increase its sales. This is the result of its non-profit character; generally any large increase in plant capacity causes an increase in capital charges and resultant unit costs until an appreciable part of the additional capacity is used. In Baltimore all water used for air conditioning is charged at the tertiary rate of the sliding scale, which is only slightly more than the unit cost of production. Therefore, it may be said that the department reserve is being exhausted without proportionate benefit.

At the present rate of use of water and increase of air conditioning, we do not see any reason for apprehension in the immediate future, but the department has been carefully considering this question and will be in a position to take action when it considers it necessary.

M. K. FAHNESTOCK (*Research Assistant Professor of Mechanical Engineering, University of Illinois, Urbana, Ill.*): The American Water Works Association is to be complimented upon its foresight in bringing to the attention of its membership the potential possibilities of air conditioning, and they are fortunate in having obtained the coöperation of two experienced men, Messrs. L. L. Lewis and L. H. Polderman, who, in the paper just presented, have given an excellent generalization of the past and present activities in the industry and a valuable prediction of what is to come. In this paper, and in the one preceding it by Mr. Lewis, which appeared in the March, 1936 number of *The Journal*, you have been given a clear picture of what constitutes real air conditioning, the factors involved, and the coördination of the factors, particularly in that division known as comfort air conditioning which has to do with the comfort and health of human beings.

It is this division of air conditioning, including both summer and winter conditioning, which has within the past few years attracted

the attention of the public, and it is this division which is now experiencing phenomenal growth and gives tremendous promise for the future. And rightly so, for is not the health and comfort of our people as important as the products of some of our industries, where, as Mr. Lewis has stated, industrial air conditioning has been in practice for some thirty years?

Within the past few years we have learned to exercise the utmost care in regard to the purity and wholesomeness of the food and the water of which we partake, and this has been an important factor in improving the general health of our people. When we consider that our bodies are continuously bathed in air and that the weight of air passing into our lungs during each 24 hours is, roughly, seven times the weight of food which we consume during the same period of time, is it not reasonable that we should give some thought to the purity and cleanliness of this air? In certain industries where the employees are exposed to air carrying dusts which are injurious to the respiratory organs, state laws and the economic pressure of paying disability and death benefits have resulted in some cognizance being taken of the importance of the air which we breath. In our trains, theatres, restaurants, and in a few of our public buildings, vast strides are being made in the number and the quality of comfort air conditioning installations. Perhaps after we have taken care of our employees and our businesses we will come to the realization that aside from furnishing some heat during the winter months we have done little else to insure comfortable and healthful atmospheric conditions for our families and for ourselves.

In the writer's opinion only the surface of the eventual possibilities in the field of comfort air conditioning has been scratched, and perhaps fortunately so, because far too little is known about the physiological effects of some of the synthetic atmospheres now being created. The air conditioning industry could well afford to be more generous in its financial support of research work in the several Medical Schools and Universities, who, although handicapped by insufficient funds and equipment, have made valuable contributions to the knowledge needed by the industry.

The paper of Messrs. Lewis and Polderman has given your utility a clear and accurate general enumeration of the requirements that air conditioning will place upon it, and although the development of water saving apparatus and the increased efficiency of refrigerating equipment will help to reduce the quantity of water needed, the

problem of sufficient capacity, no doubt, in many cases will be a serious one. As the water utility is one of service, it would appear that it has no alternative but to meet the demand, which will be an individual problem in every community. To do this will require complete surveys of existing facilities and the ability to accurately predict and provide for future requirements. It would be a great aid to the air conditioning industry if your Association could place some of the data accumulated during these surveys at their disposal. For example, in attempting to lay out a program of summer cooling tests in the Research Residence at the University of Illinois, using water as the cooling medium, it was found that very few data were available on the temperature and pressure of the water in the supply mains of the different water systems in the country. Such data would be valuable to the air conditioning engineer in New York who is designing an installation for a building in Kansas City. Incidentally, the Research Residence referred to has been operated jointly for the past four summers by the American Society of Heating and Ventilating Engineers, the National Warm Air Heating and Air Conditioning Association, and the University of Illinois. Extensive tests on cooling a typical residence in the climate of the Middle West have been made using ice, mechanical refrigeration, water from the city water mains at a temperature of 58°F., and the circulation of outdoor air at night. A large amount of practical information has been secured and published in the Journal of the American Society of Heating and Ventilating Engineers and the manuscript for a bulletin of the University of Illinois Engineering Experiment Station is now being prepared.

OPERATING EXPERIENCES AT WACO, TEXAS

By George J. Rohan

Superintendent Water Works, Waco, Texas

In the central part of the state Waco is located, a city of 60,000 people in the midst of a rich agricultural district. Cotton is the main crop, but corn, oats, wheat, fruit and a great many other products are also grown in abundance. Big railroad shops, textile mills, furniture and canvas goods manufacturers are the principal industries; Baylor University with fifteen hundred students, the United States Veterans Hospital with one thousand beds are the ranking institutions. With this preface it is perhaps time to arrive at the subject of this paper which has to do with the Waco Water Department.

My listeners are not interested in usual routine water works methods, practices, and features and within reasonable limits my remarks will be confined to items that are a little different from those commonly encountered in other municipally owned water plants.

Our water supply is obtained from Lake Waco, an artificial lake covering 2,800 acres with a 13 billion gallon capacity in which the run off from a 1,650 square mile watershed is impounded. This lake was built primarily for a water supply storage for the City of Waco, but it has a secondary and important value in flood control which has been happily demonstrated several times. The water is conveyed by gravity to and through the purification and filtration plant five miles away and thence pumped directly into the mains and into a 5 million gallon storage reservoir located at the highest point of the area served. The distribution system consists of about 180 miles of mains, some 700 fire hydrants and nearly 2,000 valves. We have 12,500 customers one hundred percent metered. Our assets are $4,250,000; our bonded indebtedness $2,114,000; our annual revenues about $250,000. The City Charter requires the Water Department to pay into the city general fund an amount equal to the interest on outstanding water works bonds. Our rates are low: 75 cents minimum, which includes the first 2,000 gallons of water, 20 cents per thousand for the next 18,000 gallons, 10 cents per thousand for the

next 980,000 gallons, 7 cents per thousand gallons for the next 1,000,000 gallons and 6 cents per thousand gallons for all over 2,000,000 gallons.

Thirty-two years ago the department had its beginning when the City of Waco purchased the interests of a private water company and at that time a governmental set-up was established which has not been changed throughout the years. The department is governed, controlled and managed by a board of five water commissioners elected for a two year term by the voters at large. These commissioners serve without pay and are charged with the duty of managing, maintaining, operating, improving, extending and enlarging the water supply system; acquiring suitable grounds, water privileges and right of way necessary to the establishment and maintenance of an efficient water plant; and further with the fixing, charging and adjusting of rates. This board is completely independent of any other authority and insofar as the affairs of the Water Department are concerned this board is supreme. There have been only thirty-one water commissioners during the thirty-two years of operation under this form of government. The original President of the board served for eighteen years, the youngest member of the present board took office in 1932 to serve the unexpired term of a deceased member. Each of the members now composing the board has been re-elected twice. We have and always have had the highest type of citizens on the Waco Water Board and I do not believe it would have been possible to have prevailed upon any of them to have run for paid office.

The custom of long tenure of office by the Commissioners is applicable to the employees all of whom have been with the department a long number of years. The superintendent with four years of service is the youngest regular employee. The thirty-eight regular employees of the department have served a total of 518 years. All of this has worked out to the benefit of the department and, as a corollary, to the citizens of Waco. With this form of government the affairs of the department are handled in a strictly business like way and never has politics entered into the picture. Our purchasing of material and supplies has invariably been based on quality and price. Cash discounts are always taken. Our long time planning for extensions and enlargements has been sensible and the rates predicated on bringing in sufficient revenue successfully to carry out these plans. An annual budget is prepared and approved by

the board at the beginning of each fiscal year and the management given full authority to carry on within the limits of the budget. A depreciation reserve is provided in the budget covering furniture and fixtures, equipment, automobiles and trucks, etc., which provides the management with means to make replacements as they become necessary without further authority from the board.

A combination store room and shop is maintained. Each item in stock is priced at actual cost plus seven percent and this sur-charge credited to stores expense, thus providing an accounting method permitting us to operate our store department without cost which is as it should be. Our working capital has always been sufficient to enable us to buy in quantities carrying the largest discount.

In our shop meters are repaired and tested and valves, fire hydrants, etc., repaired and reclaimed.

The present Board of Commissioners believe in advertising. Pamphlets have been published from time to time and distributed among our consumers giving pertinent facts and figures relating to department affairs. A special pamphlet has been prepared for students and others who visit out filtration plant in large numbers. A bit of propaganda is included on the face of our monthly bills and changed from time to time. It is usually arranged that throughout the year each civic club is addressed on the subject of the Waco City Water Works either by a Board member or one of the personnel. Our local newspapers have cooperated exceedingly well in keeping the public informed and water works conscious.

During the past several summers we have reduced our regular rates for the benefit of residential consumers and show cards are displayed in our office during this period urging the use of more water for irrigation purposes. Our board believes that a reduced summer rate is excellent advertising and good for public relationship. A reduced summer rate is somewhat questionable and perhaps not logical, but our people want it and our board thinks it wise to give them what they want. Our summer rate is 5 percent discount on the first dollar, 10 percent discount on the second dollar and 15 percent on all over two dollars.

SOME INTERESTING FACTS UNCOVERED IN A SURVEY OF PROPERTIES NOT SERVED WITH CITY WATER

By H. V. Pedersen

(Superintendent Water Works, Marshalltown, Ia.)

There are 4,656 dwelling places in the City of Marshalltown, Iowa.

How do you know there is this number, asked one of a group to whom this statement was directed?

We know this number is fairly accurate, because the water department had its meter readers count all of the dwelling places in the city, this last winter.

Do you mean to tell us that there are 4,656 houses here in a city with a population of 18,451?

I did not say houses. I said dwelling places. A dwelling place is a place where a family of two or more can live.

Do you know how many houses there are in the city?

Yes, there are 4,519 places we have classified as single family houses. There are also 6 2-family; 3 3-family; 7 4-family; 2 5-family; 2 6-family; 1 7-family; and 1 36-family apartment buildings. In addition there are 115 places which we have classified as second story flats located in the business district. Ninety-five percent of the total number of dwelling places consist of single family houses.

This is rather interesting information. What else do you know about this city, asked another of the group?

We know that, if all the dwelling places in the city were occupied, there would be room for 4,748 families. During the period of time the count was made, there were 120 vacant places including several large old houses which have not been occupied for the past eight years. There were appproximately 4,628 families in the city last winter, having an average of 3.99 persons per family.

While counting the number of dwelling places it occurred to us to find out how many places are supplied with water by the municipally owned water works. All of the apartment buildings and second

story flats are supplied with water by the city water works. We also learned that 361 of the single family houses are not supplied with public water. Of the total number of dwelling places in the city, therefore, 92.3 percent are supplied with city water. Stating this in terms of population, approximately 1,400 persons out of the total of 18,451 depend on some source other than the city water works for their water supply.

It was learned that 124 single family houses of the total number of dwelling places not supplied with water by the city are located on streets where water mains have not been laid. This means, there are 237 single family houses in the city that have never been equipped with city water, which could be provided with the comforts and convenience of city water as far as the water works distribution system is concerned. Only 2.6 percent of the total number of dwelling places in the city, representing a population of 465 are located on streets where city water is not available at the present time.

Might I ask why the Water Department collected this information? How valuable are these data after you have collected it, inquired one of the group?

These data have been a great help in formulating a definite future water main extension program. By spotting on a map the 124 single family houses located on streets where water mains have not been laid, we learned they are scattered fairly uniformly around the outskirts of the city. By scaling the map we learned that 58 blocks or approximately 4½ miles of new water mains will have to be laid in order to serve these 124 dwelling places. The average number of dwellings per block of required mains is two and the largest number of dwellings on any one block is five.

Now if we multiply the 124 dwellings by an average yearly water bill of $10 and the 23,200 feet of required extensions by $1.30, the cost per foot of 6-inch water main, it can readily be seen that a maximum income of $1,240 per year would be derived from an initial investment of $30,000 if all of the 4½ miles of mains were laid, provided of course, a water service was installed at every dwelling. Such a yearly income would be equivalent to 4 percent interest on the investment. Even at 4 percent interest it might be considered sound business by some to lay all the required mains as soon as possible. But let us analyze the situation a little closer.

The population of Marshalltown has been increasing at the rate of

about 2,000 every ten years. Judging from the number of vacant lots scattered over the city where water mains have already been laid and taking into consideration the class of new families who will most likely be attracted to the city, it is quite unlikely that 50 percent of the increase in population for the next ten years would locate on streets, where up to the present time, water mains have not been laid. Judging also by the kind of houses now located on streets where mains have not been laid and basing it upon past experience it is quite unlikely that a water service would be installed in more than 10 percent of these houses even though the water mains were laid. With these deductions in mind it appears that the Water Department is not justified in constructing more than 0.5 mile of new water mains per year for the next ten years unless some unknown factor increases the growth in population above normal.

Can you account for the fact that 237 properties have not installed water services, asked one of the group?

That question occurred to us after we were well along with the survey, but we found it was not difficult to answer it to our own satisfaction. We found that the dwellings not having the convenience of city water consists largely of one to four room, poorly constructed places. In fact, most of the places can be more accurately described as shacks. Forty of these places are located on the rear of lots where they were either moved to make room for better houses or built as temporary dwelling places until such a time when better houses could be erected. With the exception of a very few, these places are not equipped with anything resembling a cellar. None of them were provided with plumbing or plumbing fixtures when they were built and only a few have ordinary sewer drainage.

At least 95 percent of the occupants are renters paying on an average of $5.00 per month rent, ranging all the way from $3.00 for the poorest places to $10.00 per month for the better ones. All of the occupants interrogated admitted readily enough that they preferred the city water to the shallow wells they were forced to draw their supply from, but expressed the opinion that they did not see how they could pay for city water even though they were supplied with it. Most of the occupants have been on the relief rolls and are putting up with their environment because of the economic necessity. It may be a debatable question whether the owners of these properties are justfied under these conditions in spending the money to

modernize these places. It is not debatable, however, that the city with the least number of undesirable dwelling places is better off than a city having a larger number.

Are all the water services in Marshalltown metered?

No, I cannot truthfully say that they are. 37 consumers are billed on a flat rate basis. These places are but little better than the places not having water. Lack of cellar facilities make it necessary either to install a meter in the kitchen or in a meter pit. Most of the occupants are elderly folks who use less than the minimum a year. In fact some of the more aged occupants are exempt entirely from paying for the water they consume. The water department has never felt justified in putting money in meter pits for these places. At that, with only 37 flat rate consumers, the city is 99.8 percent metered.

Do you have any data comparing the number of unserviced dwelling places in other cities with that of Marshalltown?

No, I do not. Marshalltown is far from being a city of shacks as the result of this survey might indicate. On the contrary Marshalltown is one of the finest cities in the State of Iowa and the first impression one receives while driving over its tree lined boulevards is that there are no shacks at all. It seems unexcusable that a possible 900 persons out of 18,451 should be compelled to use a water of questionable quality when a public owned water supply of excellent quality is available, but I cannot say whether Marshalltown should be apolgetic or be thankful that conditions are no worse than they are. If other cities have made a survey of this nature I am not certain whether they would care to publish the data collected. But there is one thing I am certain of. The result of our little survey has been so interesting and enlightening to us I can highly recommend that every water works superintendent make a similar survey of his city, if it has not already been made.

ROMANCE IN THE DEVELOPMENT OF THE LOS ANGELES WATER SUPPLY

By H. A. Van Norman

(Chief Engineer and General Manager, Bureau of Water Works and Supply, Department of Water and Power, Los Angeles, Calif.)

Water is one of the very vital necessities of life. Wherever human life—or life in any form—exists, there also we must find water; for man in common with all other living things cannot exist without water. In Southern California, Nature has flooded the land with her golden sunshine and provided fertile valleys and fruitful plains, but she has been far less generous in providing our people with water. In fact, the original water supply for Los Angeles provided for a very limited population, but the augmenting of this original source and the consequent development of our present water system, provides a story that is truly romantic in its details.

An Indian woman with an earthen jar balanced upon her head constitued Los Angeles' original water distributing system.

To the inhabitants of the Pueblo Los Angeles in these early days, the Indian water carrier was the most important of all civic functionaries; for then, as now, every activity depended upon and revolved about the maintenance of an adequate supply of water.

In fact, it was the discovery of the Los Angeles River that brought about the establishment of the City of Los Angeles. In 1769, Gaspar De Portola, while on his historic march of exploration from San Diego to Monterey, found water here; and it was this same water supply that caused Governor Philip de Neve of Alta, California, some ten years later, to designate this spot as the logical location for a new settlement—and the first colonists, consisting of eleven families, arrived from Mexico in 1781, to found the City of Los Angeles.

This was 155 years ago, but even then the vital importance of the Los Angeles River as the basis of the new community's life and growth was recognized, and ownership to all the water of this stream was officially granted to the pueblo for all time, in a royal proclama-

tion signed by King Carlos III of Spain, the same year the pueblo was founded. Since that distant day, the City of Los Angeles has held continuously in community ownership the sole right to the water from this source.

Los Angeles' first water supply system was municipally owned and operated. It consisted of an irrigation canal, known as the "Zanja Madre," or the Mother Ditch, built through community effort, and extending from the river to a point a short distance northeast of the old Plaza. The Indian woman who dipped the water from the canal for use in the several households, was the city's first municipal employee.

As the years rolled on and the original colony grew in numbers and demanded a constantly increasing supply of water, it may be that the water-carrying ladies went on a strike. At any event, history tells us that they were relieved of further duty as water distributors, their places being taken by men who soon devised a method of delivering each family its daily quota of water by means of a barrel and a wheelbarrow; and still later these barrels were succeeded by an ox-drawn water cart.

In the early part of the nineteenth century a group of enterprising residents constructed a dam across the Los Angeles River and installed the pueblo's first water wheel. Buckets were attached to the paddles of the wheel and, as it was revolved by the force of the flowing stream, it lifted water from the river and spilled it into the intake of a canal; thus permitting the residents to irrigate land situated at an elevation considerably higher than the level of the river. Later on other water-driven wheels were installed in the canal itself, and used in the operation of flour mills; and incidentally, it is recorded, one of the town's first newspapers was printed on a press driven by this form of water power.

It is a long way from the water cart and slow-moving water wheel to the gigantic water system now owned and operated by the City of Los Angeles. Where once a single barrel on wheels served the people's needs, today more than 3800 miles of mains are maintained to carry water to the city's residents.

In recent years, the Los Angeles River is regarded by many people as something of a joke; a stream whose bed must be sprinkled regularly in order to keep down the dust.

But all joking aside, the fact remains that, save for a few scattering wells, the Los Angeles River for a period of 133 years served as

the sole water source for this community; until at last the increasing needs of the growing city exceeded its limited supply—a supply so very vital to the future of the city and its surrounding territory, located on the very edge of the desert.

To the casual observer, it is true, the river except in flood time (during the winter months) appears to be a dry river bed. This is because much of its water flows through the gravel beneath the surface of the stream bed. This peculiar characteristic of the Los Angeles River makes it more valuable as a domestic water source, for the water, while being purified through natural filtration channels, is protected also from surface contamination.

From the date of its establishment as a rude Spanish village, Los Angeles operated its water distributing system under community ownership until 1865, when the town council leased it to a private operator for three years, then leased the system to a privately owned concern, later known as the City Water Company, for a period of thirty years. After four years of litigation, the City purchased the private water company's distributing lines and equipment in 1902, for $2,000,000, and immediately put into effect a 63 percent reduction in domestic rates.

The Los Angeles River under normal conditions, was capable of supplying the needs of 250,000 people. But by 1905, the population had passed the 160,000 mark and was continuing to grow at an amazing rate. Then came a series of dry years; and the river was scarcely able to meet the city's immediate needs, much less provide for future growth.

Los Angeles could not continue to grow and prosper without an added water supply; and yet, nowhere within the immediate vicinity of the city did a single undeveloped water source of any consequence exist; and unless additional water could be brought in, the city faced certain stagnation and heavy business losses. With all its natural advantages and resources, its wonderful climate and its growing popularity as an ideal location for homes and business, Los Angeles could never be more than a very medium sized city without an additional, dependable water supply.

THE OWENS RIVER SUPPLY

About this time, far sighted civic leaders, headed by William Mulholland, then chief engineer of the Muncipal Water Bureau, began seeking another source of supply. Mr. Mulholland had

heard of the Owens River, far to the north—a stream fed by the pure sparkling snow waters of the High Sierras.

Hitching a team of mules to an old buckboard, he quietly set forth on a journey of investigation, which took him 250 miles northward, over the parched sands of the Mojave Desert and across rugged mountains into Owens River Valley, where he found the Owens River wasting this precious snow water into the salt encrusted basin of Owens Lake. For 40 days he tramped over the mountains and desert, applying conditions and possibilities there to the needs of Los Angeles and by the time he had finished there, he had formulated plans for the construction of the longest municipal aqueduct in the world—a gigantic water carrier, piercing mountain barriers, conquering a desert, and capable of delivering enough water to meet the needs of 2,000,000 people.

Mr. Mulholland reported that his plan was feasible—that it offered the only solution to a desperate situation; and that the construction of such a project would cost $24,500,00, and the people had faith in his judgment.

The first bond issue of $1,500,000, needed to purchase rights of way and start preliminary work, was submitted to the voters in 1905 and the vote in favor of this bond issue was in the ratio of 14 to 1. Thus did the citizens of a small city, with high courage and a vision of the future, lay the foundation for the metropolis of the Pacific Coast.

The building of this aqueduct—the longest in the world—was a tremendous undertaking for what was then such a small city, but Mr. Mulholland completed what he had planned. To visualize this aqueduct length, the comparison has been made that for Los Angeles to bring water from the Owens River would be equivalent to St. Louis going all the way to Lake Michigan for a water supply. The aqueduct was started in 1908 and completed in 1913, *within the cost estimate* originally set by Mr. Mulholland.

It is interesting to note that before the aqueduct itself could be constructed it was necessary for the builders to conquer and tame a vast and well-nigh inaccessible wilderness. A railroad 120 miles long was constructed to carry the thousands of tons of machinery and supplies required. More than 500 miles of highways and trails were opened. A complete pipe line system was laid out to carry water for construction work and workers in the desert. Hundreds of miles of telephone and telegraph wires were strung to connect

the fifty-seven camps erected to house men and supplies. Apparently insurmountable engineering difficulties were ultimately and invariably solved. And when completed, this aqueduct included 142 separate tunnels aggregating 53 miles in length, 12 miles of inverted steel siphons varying in diameter from 7 to 11 feet, 24 miles of open unlined conduit, 39 miles of open cement lined conduit, and 97 miles of covered conduit; also three large reservoirs, the largest of which (Haiwee Reservoir) is capable of storing more than nineteen billion gallons of water.

Built primarily as a water system, the aqueduct also provided along its course the opportunity for the development of hydro-electric energy. Thus it has blessed Los Angeles with two priceless and vitally necessary resources—water and electric power. The water invited and supplied a rapidly growing population; and this water together with the electric energy developed by the falling waters of the aqueduct system, established a foundation upon which has been builded, thus far, this city's amazing industrial growth and prosperity.

When Mr. Mulholland went into the Owens Valley, he dreamed a mighty dream; and the result of this dream was a masterpiece of engineering daring and achievement that raised Los Angeles from a modest tourist city to one of the leading cities of the United States—an engineering feat that stands as a fitting monument to the memory of William Mulholland—whose brilliant career came to a close on July 22, 1935.

Georgraphically Los Angeles is the largest city within the United States. Its municipal boundaries encircle 450 square miles of territory. The necessity of delivering water to residents, scattered over such a wide area, has required the building of a water distributing system which, in other more densely populated cities, would be extensive enough to serve a population three times greater than that of Los Angeles; and in addition to providing service for the largest city area in the nation, the Department must deliver water to consumers residing on land elevations varying all the way from sea level to 1720 feet above sea level. This necessitates heavy pumping operations in many sections of the city, and in one instance it is necessary to lift the water 570 feet.

Despite the long distance Los Angeles must go to secure its water supply, the wide territory over which this water must be distributed and the high elevations to which it must be lifted, the maximum

domestic water rate charged by the Department is 13 cents per 100 cubic feet—several cents under the average rate of the 100 largest cities in the United States.

Eight modern chlorinating plants make the water sterile before it goes into service. Sixty-nine reservoirs and tanks furnish a storage capacity of 174,450 acre feet or about 57 billion gallons. Thirteen pumping plants pump water from our underground storage basins and thirty more pumping plants raise water to the higher elevations. The necessity for these enormous storage basins becomes apparent when it is pointed out that Los Angeles is now consuming, for domestic purposes only, approximately 200,000,000 gallons of water per day.

MONO BASIN

Today, in order to make doubly sure of an adequate water supply for the City of Los Angeles, we are reaching still further north into the High Sierras, to Mono Basin—more than one hundred miles beyond the intake of our present Owens River Aqueduct.

Here in Mono Basin a collecting conduit system will pick up the snow-waters from five mountain streams now discharging into Mono Lake, which is highly saline and has no outlet.

These streams will be intercepted before entering the lake and their waters will be transported to a reservoir now under construction at Grant Lake, thence to the intake portal of Mono Craters Tunnel. This tunnel, 11.3 miles in length, will conduct these waters to the head of Owens River, whence they will reach Long Valley Reservoir, now under construction. This reservoir will have a capacity of 163,000 acre feet and will be the largest in our system. From here the water will be released into the natural channel of Owens River, whence it will reach the present aqueduct, increasing its supply by approximately one third.

This addition to the aqueduct supply will, when completed, solve our water problem for many years to come.

Very few people outside those actually interested and engaged in problems of this sort, realize that without the vision and foresight shown in the development of an adequate water supply, Los Angeles would still be a sleepy village situated in a semi-arid country, on the edge of a desert—but now transformed by the magic of water and its by-product, electricity, to the interesting metropolitan city you see before you today.

BENEFITS ACCRUING FROM THE HETCH HETCHY PROJECT, SAN FRANCISCO WATER SUPPLY

By N. A. Eckart

(General Manager and Chief Engineer, Water Department, San Francisco, Calif.)

On October 28, 1934, with appropriate ceremony, the first delivery of water from the Tuolumne River into Crystal Springs Reservoir in San Mateo County took place. This marked the completion of the initial development of San Francisco's Hetch Hetchy Water Supply Project, an enterprise representing an investment in excess of $100,000,000, and on which actual construction work had been carried on for a period of over twenty years. The Project is a monument to the engineering genius and indomitable courage of M. M. O'Shaughnessy, who, as Chief Engineer and later as Consulting Engineer, was the directing force through all those years. He did not live to witness the final consummation of his work, death cutting him off on October 12, 1934, scarcely two weeks before the dedication ceremonies.

It is the purpose of this paper to review the considerations which led to the choice of the Hetch Hetchy Project, for San Francisco's future water supply, to describe briefly the project, and to discuss, generally, the benefits which have accrued, or may reasonably be expected to accrue, from the development and use of this water supply.

CONSIDERATIONS DETERMINING SELECTION OF HETCH HETCHY

San Francisco since its earliest days had been dependent upon private enterprise for its water supply. Prior to the creation of the California State Railroad Commission, with jurisdiction over the operations of all privately-owned public utilities, the rate-fixing power for water used in San Francisco lay in the hands of the local Board of Supervisors, and resulted in the existence of a constant state of political hostility against the private company. Failure of the company to extend its service to meet the needs of the constantly expanding residential developments and occasional recurring dry

periods with threatened shortage of the water supply led to spasmodic action by succeeding governing officials and boards of supervisors, requiring investigations and reports to be made of various sources of water supply which might be acquired and developed for a municipally-owned system. It was not, however, until the adoption of its charter of 1900 that a definite movement was inaugurated which finally led to the acquisition and construction of the Hetch Hetchy Project. This charter declared for the gradual acquisition and ultimate ownership of all public utilities and prescribed that—"In securing estimates of the original cost of construction and completion of water works by the City and County, the supervisors must procure and place on file plans and estimates of the cost of obtaining from all of the several available sources a sufficient and permanent supply of good pure water."

In response to this mandate, C. E. Grunsky, then City Engineer and a man of splendid ability, made an exhaustive study of the whole water supply question, investigating some fourteen possible available sources of supply. On the basis of his studies he recommended that the Tuolumne River be selected as the source of San Francisco's future supply, as presenting "the following unrivalled advantages:

"*First:* Absolute purity by reason of the uninhabitable character of the entire watershed tributary to the reservoirs and largely within a forest reservation.

"*Second:* Abundance far beyond possible future demands for all purposes.

"*Third:* Largest and most numerous sites for storage.

"*Fourth:* Freedom from complicating water rights.

"*Fifth:* Power possibilities outside the reservation."

He added:

"It has the drawbacks of distance to overcome, requiring the construction of conduits aggregating 142 miles in length. But considering the partial pollution and the rapid rate of pollution to which all other sources may in the future be subjected, particularly nearby sources, the Tuolumne River is far superior to any other."

In setting up a basis of comparison for the several possible sources which were under consideration, Mr. Grunsky stated:

"The availability of a source of water supply . . . is determined by the quality of water delivered, its quantity, the reliability of service and cost."

"The first requisite beyond question is quality . . . if within reach at a reasonable cost, the water of unquestioned purity should be preferred and is

considered to be more available than a water obtainable at less expense, but the use of which might under untoward circumstances give rise to some calamity."

"The water supply must be an unfailing one, not alone by reason of its abundance at its source, but also by reason of the safety of the works for its delivery. . . .

"In making the financial comparison, due regard should be had to the cost of operation, maintenance and repairs."

In summing up, Mr. Grunsky placed the Tuolumne River project, of all sources studied, highest in quality and quantity of water, and the Spring Valley System to the extent of its capacity, as first in reliability of service.

It may be pointed out at this time that acquisition of the Spring Valley System by the City, with its large storage reservoirs located close into San Francisco, and the operation of these two systems in conjunction with each other, has served to strengthen the feature of reliability beyond the standard afforded by either system individually.

On the basis of Mr. Grunsky's studies and report San Francisco committed itself to this project, but before construction was under way San Francisco was called upon by a new Secretary of Interior, Mr. Ballinger, to show cause as to why the permit for developing the project on Federal lands granted by Secretary of Interior Garfield should not be revoked with reference to the development of the Hetch Hetchy Reservoir, further exhaustive studies were again required to be made of all available sources of supply and these in turn were subjected to analysis and review by a board of Army Engineers appointed by the President. In the meantime, the plan for the development of the Hetch Hetchy had been modified on the basis of a report and recommendation of John R. Freeman, who had been retained by the City, and all other projects were considered by the Army Board on a basis of comparable development.

In its report, in considering the question as to the availability of a source of the supply, the Army Board set up the following conditions to be met:

"*First:* The water yield shall be sufficient under the most severe conditions of runoff to meet the requirements of the Communities and of good potable quality.

"*Second:* The water can be collected and delivered with reasonable economy.

"*Third:* No injury shall be caused, without proper compensation, to any industries or lands that have a just claim upon the water."

The Board confirmed the selection of the Hetch Hetchy Project as the most available source and in its conclusions found:

"The project proposed by the City of San Francisco known as the Hetch Hetchy Project is about $20,000,000 cheaper than any other feasible project for furnishing an adequate supply. . . .

"The Hetch Hetchy Project has the additional advantage of permitting the development of a greater amount of power than any other."

The Board at this time estimated a power development of 115,000 horsepower which it capitalized at $45,000,000.

DESCRIPTION OF PROJECT

Before proceeding to discuss the main subject it is perhaps desirable to present, briefly, a general description of the project with some attention to those features affecting the quantity and quality of the water and certain other aspects of the system.

The water supply of the Hetch Hetchy Project is derived from some 652 square miles of watershed of the upper reaches of the Tuolumne River, of which area 459 square miles drain into the Hetch Hetchy Reservoir created by the construction of the O'Shaughnessy Dam, 79 square miles are directly tributary to Lake Eleanor and which in the future will be supplemented by the diversion of the drainage from some 114 square miles of Cherry Creek. Approximately 92 per cent of the watershed lies above elevation 6000 in rugged granite mountains and is uninhabitable except for about three months in summer. The entire area tributary to the Hetch Hetchy Reservoir and Lake Eleanor lies within the boundaries of the Yosemite National Park while the Cherry Creek drainage lies in the Stanislaus National Forest. In referring to this watershed in his report Mr. Allen Hazen stated—"It would be difficult to conceive of a more perfect gathering ground or one better adopted to produce water of greater purity. The water will be almost ideally safe."

The average yield of the Tuolumne measured above La Grange where the first major irrigation diversions are made is about two million acre feet annually.

Careful estimate of the safe yield available for San Francisco with the immediate storage development of 388,000 acre feet is 210 million gallons daily. The ultimate yield of the Hetch Hetchy Project available for water supply for the San Francisco Bay area is estimated at 400 m.g.d. on the basis of a total storage development of 1,100,000 acre feet.

The principal impounding reservoir at present developed is in the Hetch Hetchy Valley, created by the construction of the O'Shaughnessy Dam. This dam, originally creating storage capacity of 206,000 acre feet is at present time being raised some 85 feet to develop storage at this site to its ultimate capacity of 360,000 acre feet. A second reservoir at Lake Eleanor provides present storage capacity of 28,000 acre feet. Eleanor Reservoir, built primarily in connection with the operation of a small power plant at Early Intake for construction purposes, serves also as a measure of water right protection. Future plans provide for ultimate development of 218,000 acre feet storage at this site.

Water released from the Hetch Hetchy Reservoir, at present flows down the Tuolumne Canyon, approximately 12 miles, to a diversion dam (crest elevation 2356) and headworks at Early Intake, where it enters what is known as the Mountain Division tunnel 19 miles in length leading from Early Intake to Priest Regulating Reservoir.

Water released from Lake Eleanor flows about 8 miles in Eleanor Creek and Cherry River where by means of a small dam it is diverted into the Lower Cherry Aqueduct, approximately 3¼ miles in length with capacity of 200 cubic feet per second and consisting of a series of tunnels with intervening sections of concrete-lined canal, flumes and pipe. From the lower end of this canal, water is dropped through a penstock to operate the Early Intake power plant of 3000 KV-A capacity, originally built for construction purposes but since continued in commercial operation. Water discharged from this plant, except in flood periods when it is wasted back to the river, is delivered through a 60-inch steel pipe into the Mountain Aqueduct at a point about ½ mile below Early Intake. Water from the canal not required for power purposes is discharged above the Early Intake Diversion, through a connecting steel pipe.

For the upper eight miles, the Mountain tunnel is through solid granite and is unlined save for a few short sections. The flow section in this unlined tunnel is, approximately, 168 square feet. The lower 11 miles of this tunnel are concrete-lined throughout, it is of horseshoe section, 10 feet 3 inches in diameter and flow section of, approximately, 88 square feet.

Priest Reservoir at the lower end of the Mountain Aqueduct serves as a regulating reservoir, or forebay for the Moccasin power plant below. This reservoir created by the construction of an earth fill dam across a small ravine has a capacity of 2350 acre feet with water

surface elevation at 2240. Surface drainage may flow into the reservoir from limited area largely owned by City and which is fenced, though should it be found necessary at any time this surface flow, can at small expense, be intercepted by a drain ditch.

From Priest Reservoir the water flows through approximately a mile of concrete-lined tunnel, of horseshoe shape, 13 feet in diameter to a concrete surge chamber from where it enters the steel penstocks leading to the Moccasin power plant.

The Moccasin power plant, operating under a head of 1316 feet, with installed capacity of 80,000 KV-A will deliver a 24-hour average output of 60,000 KV-A at 75 per cent load factor. Plans provide for the installation of two additional units to provide for maintaining the same output at 50 per cent load factor.

The discharge from the water wheels passes into the Moccasin regulating reservoir of some 500 acre-feet capacity, formed by constructing a small earth dam across Moccasin Creek just below the power house. Moccasin Creek above the reservoir has a watershed of, approximately, 20 square miles subject to flood flows of several thousand cubic feet per second. Drainage from the entire area will be intercepted by a small diversion dam immediately above the reservoir and by-passed through the reservoir in a concrete conduit, at present under construction. Pending completion of these works it has been necessary, at times of heavy flood flow, to cut off delivery of the water on account of the high turbidity.

From the Moccasin Reservoir to the Crystal Springs Reservoir the water flows 116 miles in a closed conduit, 46.2 miles of which is concrete-lined tunnel and 69.8 miles of pie. The Foot-hill Division tunnel, of horseshoe section 10 feet 3 inches in diameter extends from Moccasin 15.8 miles westerly to the edge of the San Joaquin Valley. The tunnel is broken 5½ miles from Moccasin by the Tuolumne Canyon which is crossed at Red Mountain Bar by a submerged concrete-lined and jacketed steel siphon 9½ feet in diameter and ½ mile in length. Here provision is made for the installation of a power plant of 30,000 HP capacity to utilize the water not required in the early years for San Francisco. From Early Intake to the west portal to the Foothill Tunnel the aqueduct has a capacity of 400 million gallons daily. The San Joaquin Valley is crossed by a steel pipe of 60-inch equivalent diameter, 47½ miles in length, with capacity of 70 m.g.d. At the west edge of the Valley at Tesla Portal, connection is made with the Coast Range Tunnel extending 29.1 miles to Irvington

Portal on the west slope. This tunnel is broken at Alameda Creek which is crossed by a 69-inch diameter steel cylinder reinforced concrete pipe siphon a little over 3,000 feet in length. This tunnel is concrete lined of circular section 10 feet 3 inches in diameter, but due to flatter grade than the upper tunnel the capacity is reduced to 250 m.g.d.

At Irvington Portal is installed a chlorinating and ammoniating plant equipped with five 300-pound vacuum type, solution feed chlorinating machine and one 200-pound solution feed ammoniating machine.

From Irvington Portal to the east portal of Pulgas Tunnel two lines of pipe, of 60-inch and 66-inch nominal diameter, extend approximately 21.3 miles, except for the submarine crossings at Newark Slough and San Francisco Bay which are made with 42-inch cast iron flexible joint pipe in the original line and with 54-inch concrete jacketed steel flanged pipe in the line recently completed. Pulgas Tunnel, $1\frac{3}{4}$ miles in length, is similar to the Mountain Tunnels, and concrete lined throughout extends to Crystal Springs Reservoir.

The Pulgas outfall where the water from the Hetch Hetchy Aqueduct discharges into Crystal Springs Reservoir at elevation 287 marks the present terminus of the Hetch Hetchy Project, from this point on the old Spring Valley System is used for transmission and distribution of the water.

Under the Raker Act, San Francisco is required to utilize her existing sources of supply as far as available before drawing upon the Tuolumne source, so in Crystal Springs Reservoir Hetch Hetchy water mingles with that collected from the tributary watersheds and other local sources.

Water released from the Calaveras Reservoir of the old Spring Valley System, located in Alameda and Santa Clara Counties, may be discharged through a connecting pipe line by gravity directly into the Hetch Hetchy Aqueduct at the Alameda siphon, a short length of steel pipe connecting two sections of Coast Range tunnel south of Sunol. Calaveras Reservoir with a capacity of 32.8 billion gallons impounds the runoff from, approximately, 135 miles (square miles) of watershed in Alameda and San Mateo Counties. An aerator plant and a chlorinating plant immediately below the dam serves to aerate and sterilize the water released from the reservoir before it enters the connecting pipe line leading to the Hetch Hetchy Aqueduct.

DISCUSSION OF BENEFITS ACCRUING

San Francisco has invested over $100,000,000 in the Hetch Hetchy Project, in addition to the $41,000,000 paid for the acquisition of the Spring Valley, to secure an ideally pure source of water supply, perpetually protected against any serious pollution, abundant not only for its own but for the needs of the dependent area of the entire Peninsula for all time. The necessary dams, aqueducts and appurtenant water works and electric power plants are of sound engineering design and first class construction, econimically built to deliver the water from this source by gravity to Crystal Springs Reservoir from which point it is now being delivered through the old Spring Valley System to San Francisco.

These are the physical assets. In what manner and to what extent do the people of San Francisco and other communities benefit thereby? This is rather a broad subject and will be discussed in general terms under several heads.

1. Improved sanitary and physical characteristics

Water as impounded in the Hetch Hetchy Reservoir is of the highest sanitary standard, unfortunately it can not be delivered to the ultimate consumer in its original purity and quality. In its transmission to San Francisco it is exposed to possible contamination from surface drainage at serveral points: namely, the channel of the Tuolumne River wherein water released from O'Shaughnessy Dam flows for some 12 miles to Early Intake, Priest Reservoir, Moccasin Reservoir, and in the Coast Range Tunnels, due to seepage of highly mineralized ground water. As water from Hetch Hetchy is discharged into Crystal Springs Reservoir for delivery to San Francisco, it tends to assume the sanitary and physical characteristics of the local waters stored therein. As mentioned, under the terms of the Raker Act water from local sources must be used to the available capacity of those sources before diverting water from Hetch Hetchy.

It is desirable from an operating point of view to deliver to consumers as nearly as possible water of uniform quality, which is accomplished by the mixing of the waters in this large reservoir. Crystal Springs and the other Peninsula reservoirs have a combined capacity of 29.5 billion gallons, with watershed area of about 36 square miles all of which, with very minor exception, is owned by the Department and is fenced and patrolled. The clean, naturally wooded, and protected watershed, and the long period of storage,

contribute to produce a raw water of excellent sanitary quality—in fact, during the 75 years of its history there has not been a single death due to a water-borne disease traceable to the water supply. As a result of the several factors tending to equalize the sanitary qualities of the Hetch Hetchy and local waters, and the excellent quality of the local supply, little improvement in sanitary quality was to be expected.

The water has not been in use for a sufficient period for our Department of Public Health to note any effect upon the public health statistics.

Apparently, certain direct benefits accrue as affecting the amount of chemicals used in the treatment of the supply, and while it may be somewhat premature to determine at this time the extent of such benefit, mention may be made of the fact. Our records indicate that the algae growth in the Crystal Springs Reservoirs during the year 1935 was but 60 per cent of that occurring in 1934, but three copper sulphate treatments were required in 1935 as against seven in 1934. Records so far for the year 1936 indicate conditions similar to 1935. The Hetch Hetchy water has a tendency to slightly reduce the temperature of the water in the reservoir, the yearly mean temperature for the year 1935 being 60.3 as against 61.4 for the preceding year. There are several factors which affect algae growth; cooler water and reduction of the amount of mineral and organic matter in the water all tend to reduce the growth, while on the other hand reduced turbidity in the lake permits greater penetration of the sunlight and tends to stimulate algae growths.

During the past year, due to the smaller amount of organic matter present, it has been possible to reduce the chlorine dosage at the reservoir outlet from an average of 4–5 to 3 pounds per million.

In recent years, due to increasing consumption and seasons of deficient rainfall, the end of the dry season has found these Peninsula reservoirs greatly depleted. As a result of this low stage the turbidity of the water at these times was greatly increased due to the inflowing water cutting through deposits of fine sediment, wave action on the sediment and the fact that the reduced volume of storage afforded shorter period of retention for sedimentation. Delivery of Hetch Hetchy water has made possible the filling of the reservoirs and provides assurance of maintaining the storage at near capacity, which will avoid in large measure the extreme turbidity previously occurring, and effect a material reduction in the chlorine require-

ments which were at an extremely high rate during periods of high turbidity.

There possibly has been some slight improvement in the quality of water delivered to consumers in San Francisco with respect to taste and odor, as is evidenced by the reduction in the number of bad water complaints, notwithstanding the fact that there have been innumerable shut-downs throughout the system due to extensive additions and changes of flow in our gridiron system during the past year. This, however, we are inclined to attribute more to the higher levels we have been able to maintain in our Peninsula storage reservoirs, enabling us to withdraw water at elevations offering the best quality of water.

Beyond these present benefits we have assurance for all time that the quality of the water at the source will not deteriorate, that with necessity, any contaminating influence of surface water will be eliminated by further diversion, and that with the increasing ratio of draft from Hetch Hetchy, improvement in quality of water delivered to San Francisco will progress continuously.

2. Chemical qualities

Hetch Hetchy water is extremely soft and of very low mineral content, samples from the reservoir show a mineral content of from 13 to 25 p.p.m. and a hardness of 5 to 12 p.p.m. On its way to Crystal Springs Reservoir additional mineral enters solution so that at Pulgas Outfall we find the mineral content increased to 140 p.p.m. and the hardness to about 30 p.p.m.

The mineral content and hardness of the local waters impounded in Crystal Springs Reservoir prior to delivery of Hetch Hetchy water varied over quite a wide range depending in large degree upon the seasonal runoff into the reservoir and the amount of contribution from other local sources of supply, such as the Pleasanton Wells, Sunol filter beds and Calaveras Reservoir. In October of 1934 just prior to delivery of Hetch Hetchy water, water in Crystal Springs (with 3,350 million gallons impounded) showed a mineral content of 252 p.p.m. and hardness of 182, San Andres which derives its supply partly from Crystal Springs and partly from direct runoff showed mineral content 228 and hardness 149. At the present date (May 18) with about 15 billion gallons impounded the mineral content is 115 p.p.m. and hardness about 80 p.p.m.

Representative mineral analyses at various points of the system are shown in table 1.

In a general way, the columns from 1 to 5 show the progressive change in the chemical content of the water as it moves from the Mountain source to the Peninsula storage system which provides, in the main, the water distributed in San Francisco. Column 6 gives the analysis of the water in Crystal Springs Reservoir as made just prior to delivery of Hetch Hetchy water, which took place October 28, 1934.

TABLE 1

Analyses of water at various points—Hetch Hetchy System

Mineral content in parts per million

	HETCH HETCHY RESERVOIR	MOCCASIN RESERVOIR	IRVINGTON PORTAL	PULGAS OUTFALL	CRYSTAL SPRINGS	CRYSTAL SPRINGS PRIOR TO HETCH HETCHY
	1	2	3	4	5	6
Silica and insoluble	3.1	3.8	5.3	4.6	3.9	6.4
Sodium	1.6	2.3	32	12	8	24
Calcium	1.6	1.2	2.5	16	17	46
Magnesium	0.35	0.52	0.68	3.3	4.4	16
Iron	0.13	0.12	0.18	0.10	0.17	0.2
Aluminum	1.0	0.28	0.29	1.1	2.6	0.3
Bicarbonate	4.9	8.6	43	54	76	164
Sulphate	2.5	2.2	26	29	17	38
Chloride	2	2	13	8	10	22
Alkalinity	4	7	35	48	62	135
Total solids	25	22	108	141	102	252
Hardness	12	7	12	30	74	182
pH	6.9	7.1	7.6	8.3	7.3	7.9
Turbidity	1—	1—	1	1	2	4
Temperature	70°	57°	61°	54°	52°	61°
Date	8/8/35	8/8/35	8/6/35	12/6/35	1/9/36	10/17/34

The hardness of water is perhaps the most common index for comparing waters as to the chemical quality as affecting its use in the household and industry. It is probably fair to assume that water delivered to San Francisco in the future will have an average hardness of not more than 80 p.p.m. as compared with 180 p.p.m. prior to delivery of Hetch Hetchy water. Whipple in his book the *Value of Pure Water* as a basis for comparing the relative value of

waters of different degrees of hardness, placed a penalty on the harder water equivalent to 10 cents per million gallons for each part per million difference in hardness. On the basis of our present consumption of 55 million gallons daily this would amount to some $200,000 per year. On the basis of studies made more recently by Hudson & Buswell (*Journal*, June, 1932), this reduction in hardness would effect an annual soap saving of approximately 80 cents per capita or $560,000 per year.

3. Quantity

The completion of the Hetch Hetchy Aqueduct and delivery of water from this source into our Peninsula system forever laid the spectre of a "water famine" which had arisen from time to time in seasons of scant rainfall to confront the people of San Francisco and to give the officials of the old Company and those who succeeded to their responsibility the keenest anxiety and on several occasions to force definite and drastic action to augment the water supply. We need only to go back to 1930, the year the City acquired the system. Entering the dry period in May, with storage of 16,475 million gallons, it was apparent that in the event of a succeeding season of subnormal rainfall there was possibility of absolute depletion of the supply in the following year. As an immediate relief measure the Department put down some 17 wells and constructed the necessary pumping plant and developed some 6 m.g.d. in San Francisco, and at the same time steps were taken to secure the necessary legislation and appropriation of funds to bring in a supplementary supply from the San Joaquin River or from the East Bay Municipal Water District. In October an agreement was entered into with the District, surveys were made and 13 miles of right of way acquired by December 25 when construction of the connecting line was commenced. This line, which was 36 inches in diameter for about one-half of its length and 44 inches for the remainder, and the necessary pumping station, were put in service on February 22, 1931, 59 days after starting field work, at a cost of, approximately, $1,000,000.

During the period of its use, until January 12, 1932, a total delivery of 7 billion 880 million gallons was made—without which San Francisco's supply would have been absolutely exhausted September 1st of 1931. To be freed from this constant threat of a water shortage and to be assured of a supply adequate probably for all time is a benefit that can not be measured in monetary terms for it may be

truly said that a community must pay whatever price that is necessary to secure a water supply adequate to meet its requirements. An abundant supply of water of good quality is essential to the industrial development and growth of a community, for such growth and development can not extend beyond the capacity of the supply to meet its requirements.

The Hetch Hetchy Project has been developed not only to provide for San Francisco's requirements but also with a view to meeting the needs of what may be designated as the South Bay Metropolitan area. This Metropolitan area broadly is considered to include in addition to the City and County of San Francisco, that portion of San Mateo County in the Bay drainage area, the Santa Clara Valley, and the southern portion of Alameda County.

Water productivity available to these areas, exclusive of the Hetch Hetchy supply, on the basis of studies made by Mr. M. J. Bartell in 1928 and 1930, was as follows:

	m.g.d.
San Francisco Water Department sources	54*
San Francisco private sources	12
San Mateo County Bay slope	10
Santa Clara Valley exclusive of irrigation	20
Southern Alameda County	8
	104

The Hetch Hetchy Project with the enlargement of the O'Shaughnessy Dam now under way has a developed capacity of 210 m.g.d., with future available storage developments the potential capacity of the Project is a safe yield of 400 m.g.d. which combined with the local supply provides a total in excess of 500 m.g.d.

On the basis of a recent population forecast for the region involved, which forecast was based on careful and exhaustive studies and a consideration of the per capita consumption of water in the various communities in this South Bay Metropolitan area, table 2 was developed by Mr. Bartell, in a report on the subject.

While it might appear presumptious to forecast a population growth for a period in excess of 160 years, this has been done with a full knowledge of the limitations on a basis that appears, perhaps, as reasonable as any that might be developed. In his studies, Mr. Bartell reached the conclusion that the population of the area in-

* Exclusive of Lake Merced and Sunset wells capacity 2½ and 6 m.g.d., respectively.

volved will reach a fairly definite saturation point, which can be gaged with some fair degree of accuracy from the experience of older Metropolitan areas. The limit of the water requirements for the area can thus be established with possibly an equal degree of accuracy. The significant thing then is, that the combined capacity of the Hetch Hetchy system and the local supply is fairly commensurate with the ultimate requirement of this entire area and as the delivery of water can be coördinated to meet the requirements of growth we are little concerned as to whether or not the population curve is accurate as to the rate at which the population increase takes place.

TABLE 2

Estimated future water requirements of San Francisco and South Bay region

(Million gallons daily)

YEAR	SAN FRANCISCO	SOUTH BAY AREA	TOTAL
1940	73	46	119
1950	83	62	145
1960	94	84	178
1970	106	106	212
1980	120	138	258
1990	137	170	307
2000	155	202	357
2020	180	255	435
2040	190	300	490
2060	200	300	500
2080	200	315	515
2100	200	315	515

4. Electric power supply

Incidental to the water supply, electric power has been developed at two points: Early Intake and Moccasin Creek. The plant at Early Intake with a capacity of 3000 KV-A, as previously mentioned, was originally built as a temporary plant to provide power for construction purposes. Under orders from the Power Administration during the War, surplus power was disposed of through the Pacific Gas & Electric Network, the plant has continued in service ever since on a commercial basis, bringing in during that period revenue in excess of $800,000 in addition to the value of the power supplied for construction purposes. The Moccasin Power Plant with installed capacity of 80,000 KV-A was completed and put into service August 14, 1925. The plant is designed to utilize the full continuous flow of

620 cubic feet per second (400 m.g.d.) delivering power on the basis of a 75 percent load factor. Actually, it has been able to operate on a continuous flow of somewhat in excess of that amount. Electric energy from this plant, in an attempt to meet certain requirements imposed under congressional act conveying certain privilege in the National domain, has been disposed of ever since under an agency agreement with the Pacific Gas & Electric Company.

The cost of constructing these plants has been borne by Hetch Hetchy bonds. They represent an investment chargeable to electrical development of, approximately, $26,000,000. The following from the Income Statement for the year 1934–35 is presented as typical of the financial benefits accruing to the City:

Moccasin Power Revenues		$2,211,951.72
Early Intake—Revenues		92,373.67
		$2,304,325.39
Other Revenues, rents, interest		38,890.12
Total Revenue		$2,243,215.51
Operating Expenses	$362,303.09	
Allowance for Depreciation	175,000.00	
Bond Interest	691,294.50	1,228,597.59
Net Profit		$1,114,617.92

For the entire period since commencement of the Moccasin Plant, we have, similarly:

Gross Revenues	$21,876,864.43
Expenses, including Depreciation, Interest, etc	13,535,958.58
Net Profit	$8,340,905.85

Besides the Moccasin and Early Intake plants, there are a number of other power developments which may be made. Plans provide for the future installation of two additional units at Moccasin so that this plant may operate at full continuous flow on a 50 percent load factor,—other plants for which preliminary studies have been made include:

	KV-A
Red Mountain Bar capacity	15,000
Early Intake future capacity	42,000
North Mountain	24,000
	81,000

In addition to these, there are several other possible sites in connection with proposed reservoirs which will, ultimately, have to be developed.

5. Operating benefits

Water from Hetch Hetchy and Eleanor Reservoirs is delivered to Crystal Springs Reservoir, (flood elevation 288) and thence through connecting pipes to the University Mound Reservoir in San Francisco (elevation 172) entirely by gravity. From this latter reservoir 40 percent of the water used in San Francisco is distributed to consumers without pumping. Freeman, in his report on the Hetch Hetchy Project, by capitalizing the pumping costs, placed the value of gravity delivery of the water supply at these elevations at $5,000,000 for 100 m.g.d. and $20,000,000 for the ultimate delivery of 400 m.g.d.

Construction of the Hetch Hetchy Aqueduct, specifically that portion between Alameda Creek and Crystal Springs Reservoir, has made possible certain operating economies in the delivery of local water from the Alameda sources, by eliminating the necessity of operating the Pulgas and Belmont booster pumping stations. Formerly, water released from Calaveras reservoir flowed down Alameda Creek to Sunol, from here together with water from the Sunol filter galleries and that pumped from the Pleasanton wells, it was transported through the Sunol Aqueduct to the Niles Reservoir (elevation 181) and from which point part was delivered through the Bay Crossing Pipe and the Pulgas Booster pumps, against an operating head of 140 to 207 feet, into Crystal Springs, and part was delivered through the old Alameda pipe line to the Belmont Pumps, which under an operating head of 260 to 325 feet boosted it to the University Mound Reservoir. A pipe line connecting the Calaveras reservoir outlet with the Hetch Hetchy Aqueduct at the Alameda Creek siphon, permits gravity delivery direct to Crystal Springs. A small electric station to be installed near Irvington will boost the small amount of water derived from the Pleasanton Wells and Sunol into the main Bay Crossing Pipe Line at that point. The savings effected by these changes approximate $93,000 annually.

The dependable increased supply from Hetch Hetchy may be credited with certain other economies: (1) By sustaining the water level in Crystal Springs at a higher elevation, which will now be possible, some $12,000 annual pumping charges will be saved, due to reduced pumping head in lifting water from Crystal Springs to San

Andres reservoir, from which reservoir gravity delivery is made to distributing reservoirs at higher levels in San Francisco; (2) it has permitted the discontinuance of the use of Lake Merced as a regular source of supply thereby effecting an annual saving of some $35,000 due to shutting down the Lake Merced pumps; (3) similarly, the Sunset Wells and pumping Station have been discontinued with a saving of $38,000 per year, the saving in both instances make due allowance for the added burden transferred to the Crystal Springs pumps for serving the higher elevations; (4) the continued heavy draft on the Pleasanton Wells had seriously lowered the water table in the Pleasanton Valley and under an agreement with land owners in that district, the City, as successor to the Spring Valley Company is obligated to pay the additional power charges involved in connection with the operating of these private wells, resulting from the lowered water table, temporary discontinuance of the draft from our Pleasanton Wells is rapidly restoring the water table which will effect estimated savings of some $16,000 for these power changes.

The total savings in all of these pumping operations and power charges is estimated at $194,000 per year.

While, as previously pointed out, the amount of copper sulphate per million gallons has been reduced, this will possibly be more than offset by the requirement for treating the large volume of water which will be maintained in local storage.

Similarly, any reduction in chlorine dosage required at Crystal Springs outlet will be more than offset, for some time at least, by the expense involved in the necessary chlorine treatment at Irvington and Tesla Portal.

6. Indirect benefits

Aside from those direct benefits which accrue from greater supply, the improved quality of the water and the operating economies, there are certain indirect benefits which will be referred to briefly.

The storage development of 388,000 acre feet on the Tuolumne watershed, a tributary of the San Joaquin River contributes to the regulation and flood control of that river, helping to maintain the low water flow in the dry-river period and flattening out the flood peaks, all of which directly benefit the farmer and riparian owners, who in turn contribute to the support of the industries and business of San Francisco.

Under provisions of the Raker Act the City was required to con-

struct and maintain certain roads and trails in the vicinity of the Hetch Hetchy Valley, for the benefit of the general public, making accessible to them portions of this wonderfully scenic country. At Mather, about nine miles from Hetch Hetchy Reservoir, the City has developed a summer recreational camp, where for a moderate charge a two-week's vacation may be spent with facilities for swimming, horseback riding, fishing and other similar activities. Here, also, is provided an auto camp where the tourist may stay over night or spend a day or two at nominal charge. Sanitary sewage disposal is provided for at these camps to avoid possible contamination of the water supply.

The employment provided in the construction of this Project, involving the expenditure of over $85,000,000 for labor and materials, has contributed in no small degree to the prosperity of the small towns in the vicinity of the work, and to the manufacturers and dealers in materials, equipment and supplies, in San Francisco and elsewhere.

Mention must also be made of the inestimable value of the favorable advertising which San Francisco has enjoyed as the result of the great interest which not only the engineering profession but the public generally has taken in the several elements of the Project and the progress of the work. During the construction period, innumerable excursions of civic bodies and fraternal organizations were conducted over the work, besides a regular bus service for tourists which was operated from Yosemite Valley to the Hetch Hetchy Dam during each summer season. Records kept show that during the past four years more than 80,000 people visited the O'Shaughnessy Dam, over 50 percent of whom were from outside of San Francisco. The volume of publicity which was given to the completion of the Project in the newspapers throughout the United States was in excess 10,000 column-inches,—all of which must inevitably redound to the great benefit of the City in attracting population and industry.

SUMMARY

Summarizing the foregoing, we may list the benefits which have accrued from the construction of the Hetch Hetchy Project, briefly, as follows:

1. San Francisco has secured a source of water supply of the highest

sanitary standard and which will maintain that standard in perpetuity.

2. The water is of excellent chemical quality with mineral content of 13–25 p.p.m. and hardness of 12 p.p.m. The dilution of the local supply with increasing volume of this mountain water is greatly improving the chemical qualities of the water delivered to consumers. The hardness has been reduced from, approximately, 180 to 80 p.p.m.

3. The question of adequacy of water supply has been solved for all time to come. The 400 m.g.d. available supply is sufficient not only for San Francisco's ultimate needs, but also for that of the entire South Bay Metropolitan area.

4. San Francisco has acquired an electric power supply of 80,000 KV-A producing a present revenue of, approximately, $2,000,000 per year, with further potential developments which will more than double this capacity.

5. Direct operating benefits due to elimination of pumping stations representing actual savings of, approximately, $194,000 per year.

6. Various indirect benefits have accrued resulting from: Contribution to flood control of the San Joaquin; the opening of roads and trails and recreational facilities in the Hetch Hetchy region; the added employment and increased business incidental to the construction of the Project; the favorable advertising which the Project has directed to the City of San Francisco.

DISCUSSION

F. E. DeMARTINI (*Water Purification Engineer, Water Department, San Francisco, Calif.*): The paper presented by Mr. Eckart is a very thorough and interesting report of the Hetch Hetchy project and its benefits to San Francisco and the South Bay Metropolitan area. In the history of the development of the project, and of the dealings and decisions of the governmental agencies that had jurisdiction in the matter, Mr. Eckart has given a very clear picture of the many obstacles which had to be overcome to realize the acquisition of this water supply for San Francisco.

It has been pointed out that the Hetch Hetchy water is of excellent quality bacterially, physically and chemically, at its source. In its 142-mile trip to Crystal Springs Reservoir, it is subject to changes in character due to various factors, chief of which are: entry of water from Moccasin Creek into Moccasin Reservoir; entry of tunnel

drainage water, principally in the Coast Range tunnels, and finally mixture with the local waters of the Peninsula Reservoirs.

The flow from Moccasin Creek may have turbidities of several hundred parts per million during storms, and more often than not three to five 10-cc. tubes are positive for the B. Coli Group. Mr. Eckart has explained that this flow from Moccasin Creek will be eliminated by a diversion dam in the creek and pipe line under Moccasin Reservoir. Infiltration water in the Coast Range tunnels is highly mineralized, but is diluted so much by the tunnel supply that it has no serious effect, in fact, it raises the alkalinity, calcium content, and pH to more favorable values with respect to the corrosion tendencies of the water. The crenothrix introduced with this tunnel infiltration has been a problem, but has not caused serious impairment in quality. Chloramine treatment has been found to control it successfully.

The mixture with the local waters increases the hardness, but even so the hardness averages only 80 p.p.m. in Crystal Springs Reservoir and this will probably be reduced, as a greater proportion of the Hetch Hetchy water enters the local reservoirs. A possible advantage due to the mixture with local water may be the increase in iodine content of the water served to the consumers. It is questionable, however, if the Hetch Hetchy water is as low in iodine as some expect. A half dozen analyses on samples below Moccasin Reservoir indicate an iodine content of 1.5 p.p.b. which compares favorably with most of the local supplies ranging from 1.0 to 3.0 p.p.b. Laboratory studies are being conducted, using a simplified procedure, with a view to learning more about the iodine content of both the Hetch Hetchy, and the local supplies.

Mr. Eckart has pointed out, and it should be emphasized, that the local supplies in San Mateo and Alameda Counties are of excellent quality bacterially and chemically. Algae growths and turbidities (at times of low reservoir levels, as in the past) have caused difficulties. By permitting higher lake levels at all times, the Hetch Hetchy supply reduces turbidity. During the past year, copper sulphate treatments were fewer than usual. It is perhaps too soon to draw definite conclusions on the net effect of Hetch Hetchy water on algae growths.

The provision of an abundant supply will permit thorough flushing of the distribution system. This program will do more to eliminate complaints of bad water than any other factor. The water purifica-

tion division investigates certain types of complaints which are not explained by obvious causes. However, except for an occasional unusual problem, most of these complaints may be traced to deposits, growths, or disturbances within the mains. Flushing within the district affected is of temporary benefit only, but a carefully planned program for the entire city should be of great help.

Prior to the delivery of Hetch Hetchy water to Crystal Springs Reservoir, laboratory control was carried on by the Water Department, to a limited extent. The problems resulting from the introduction of this new water supply have necessitated studies and laboratory control that have led to expansion of the purification division. There is no question about the value of this work and inasmuch as the Hetch Hetchy project has contributed to the development of this sanitary consciousness laboratory control may be counted in part, at least, as a benefit accruing from the Hetch Hetchy project.

THE DUAL USAGE OF WATER FOR DOMESTIC AND IRRIGATION PURPOSES

By J. B. Lippincott

(Consulting Engineer, Los Angeles, Calif.)

Cities and communities grow due to the local existence of basic natural opportunities around which they develop. The growth of San Francisco and New York was largely because of their commercial opportunities offered by their harbors. The opportunity of cheap water power stimulated the development of many New England towns. Mineral deposits have created cities like Pittsburg and Birmingham. The prosperity of Chicago is built on the agricultural production of the great Mississippi Valley region. The growth of the towns of Southern California springs from the value of its agricultural products derived from lands put under irrigation. Southern California produces the greatest agricultural values per acre of any section of the United States. The encouragement of irrigation, therefore, is basic in this latter section. The study of this fact as applied to this latter section is therefore the purpose of this paper.

The Owens Valley Aqueduct of the City of Los Angeles, completed in 1913, has a capacity of 450 second-feet or 294,000 acre-feet a year allowing for interruptions. This water was supplemental to the then existing local supply of 71.5 second-feet which was serving the municipality so there was a water surplus for the early years of operation. The population was about 400,000 at the time of completion. The policy then adopted by the Los Angeles City Water Board for putting this surplus water to beneficial use, has now been in successful operation for twenty-three years. Because a similar but much larger problem confronts the Board of the Metropolitan Water District now nearing completion, for the disposal of its Colorado River Aqueduct water, in excess of the present municipal requirements of its member units, the history of the Los Angeles City policy as applied to the Owens Valley Aqueduct becomes instructive. It also may have application to other municipalities in the semi-arid region.

While it is not of record, the underlying principle which motivated the building of both Southern California aqueducts has been:

(a) To main an adequate water supply for urban use and all other types of existing local industry including agriculture,
(b) To provide an adequacy for future municipal requirements,
(c) To aid in the development of areas adjacent to the municipalities.

These two aqueducts are really mutual water companies to be operated without profit. Their real intent is to supply an underlying vital resource for the region upon which a municipal, industrial and agricultural civilization can expand. It is important to keep these principles in mind in studying the method for the disposal of surplus water occurring in the early years of operation of these systems.

LOCAL WATER SUPPLY

In 1898 the writer initiated for the U. S. Geological Survey, a study of the groundwater problems of Southern California. By 1904 it became apparent that these supplies, in most localities, were being overdrawn. It was the existence of this great underground body of water that permitted the rapid growth of Southern California. In the past apparently adequate water of good quality could be obtained at small expense for all. Over 90 percent of the water of this region was obtained from wells (State Engineer Bulletin 45, p. 18).

The Los Angeles River which originates from the underground gravels of the San Fernando Valley, is a stream of unusually constant flow. It was the main source of supply of the city prior to the building of the Owens Valley Aqueduct.

In 1905 at the termination of a series of extremely dry years a water shortage was experienced by the rapidly growing town. The river supplemented by a few wells amounting in all to 71.5 second-feet (Ann. W. D. Report, 1907), had been adequate to care for the prior needs of the city. A study of the future requirements demonstrated that additional water was necessary for the growing community. It was realized that temporarily such addition could be obtained from wells in the San Gabriel Valley or the Coastal Plain, but that large extractions therefrom would deplete the supply essential to communities that were commercially tributary to the city. The wise policy was adopted by the City Water Board of drawing upon some distant area for additional water, where the minimum injury would occur from its exportation to the city. The Water Department had an

extended investigation made of all feasible sources. The attention of Mr. William Mulholland, Manager of the Los Angeles Water Department, was called to the Owens River by Frederick Eaton, who formerly had been both City Engineer and Mayor as well as a former resident of Owens Valley. These two men, without adequate maps, but both with unusual courage and judgment, aided only by aneroid barometers and their personal observation, made a reconnaissance of the possible route across rugged mountains and deserts for an aqueduct 238 miles in length to the present San Fernando reservoir sites. Mr. Mulholland recommended the acquisition of contracts for the purchase of lands and water rights to be followed by preliminary surveys.

The City Water Board was composed of men of marked ability. Before making public announcements they entered into these contracts, for which they were personally responsible, for the purchase of large areas of land and canals in Owens Valley. These having been secured the project was announced and a bond issue of $1,500,000 was requested for these purchases and for the surveys. These bonds carried by a vote of 14 to 1. In 1907 an election was carried by a vote of 10 to 1 for $23,000,000 additional for construction. The population of Los Angeles then was 210,000.

In March 1911 when this aqueduct was nearing completion, the City Water Board appointed a commission of engineers composed of John H. Quinton, W. H. Code and Homer Hamlin, to study the water requirements and the area, over which this supply should be distributed. The then municipal distribution system covered 24,000 acres upon which two acre-feet per acre per annum was found to be used. They reported that the supply from the new aqueduct would permit of its distribution over much greater areas than then existed within the municipal boundaries. This engineering board found that the amount of water required per acre for irrigated land was the same as for the urban use. The deduction followed that if surplus water was put to agricultural use on adjacent areas over which the city could grow, a transition of use from agriculture to municipal could occur without affecting the volume of water required for such area and therefore there would be no occasion for withdrawal. This is a most important conclusion.

Upon this theory an area was recommended by this engineering commission upon which the surplus waters of the Owens River Aqueduct could be placed to best advantage. This area extended

along the foothills from the San Gabriel River to Santa Monica and Redondo and included the San Fernando Valley, which latter has an area of 113,000 acres. The area was mostly outside the boundaries of the city and it had a very deficient water supply.

Lands in the neighborhood of Los Angeles when once supplied with water for agriculture had previously been transformed from farms to towns. The Pueblo of Los Angeles was developed on the lands served by the Madre or Mother Ditch from the Los Angeles River. Pasadena was founded as the citrus growing Indiana Colony and was served from the Arroyo Seco. Hollywood was transformed from dry lands by the West Los Angeles Water Company which obtained its water from wells located in San Fernando Valley.

The unwritten rules established by the City Water Department were: (1), when water was once put upon an area there never should be the necessity of its removal; (2), that the area of the city should not be expanded beyond that which could be permanently supplied; (3), that surplus water above the requirements for domestic use should be applied to irrigation of such areas at a price farmers could afford to pay.

The boundaries of the lands admitted to the city, were limited at that time, to the elevations to which deliveres could be made by gravity.

The benefits to the city from the use of water are thus direct and indirect. It is such indirect benefits that justifies the U. S. Reclamation Service in building irrigation works for the arid regions at public expense without interest charge and the adoption of much the same policy by the British government in India.

Agricultural use of its surplus water was encouraged by the city: (1), to hold the acquired water rights, by putting the water promptly to a beneficial use; (2), irrigating dry areas permitted the expansion of the urban growth of the city thereon; (3), a prompt revenue could be obtained from this surplus water, (4), there results a broad increase in commercial activity, in land values and tax revenues, (5), aqueduct water used for irrigation in the San Fernando Valley partly returns to the river above the intakes of the Water Department. A ten-year record of the city Water Department has determined that 27.5 percent of the irrigation water used in the San Fernando Valley returns to the river.

The revenue of the City Water Department from the agricultural sale of water in 1929 was $698,000. From 1915 to 1935 inclusive

it has aggregated $9,198,334. The rate at which agricultural water is now being sold is $6.53 an acre-foot on areas where the return water reaches the river. This cost provides proportionally for the water used for taxes, depreciation, maintenance and operation of the aqueduct. At present the use of agricultural water within the city has apparently passed its peak. The volume of irrigation water now used is less than the local water supply of the city, leaving all the waters of the Owens Valley Aqueduct available for municipal use.

In order to put into practical effect the use of this agricultural water, a state law was approved June 13, 1913 (Senate Bill No. 1753) known as the County Water District Act. This provides for the formation of a district and the voting of bonds for the building of a distribution system. Two districts were organized in the San Fernando Valley embracing about 85,545 acres. The law states that after such bonds are voted and the distribution system provided for, such area may then be annexed to the city, and if the city owns its own water works, upon such annexation, the District ceases to exist and its distribution system becomes part of the City Water Department system. The project built under this act in the San Fernando Valley consists of steel pipe operated under pressure suitable for either domestic or agricultural purposes and is now a part of the city water system. In 1915 the major portion of the valley was annexed to the city. The transition from farm to town is going on. From 1924 to 1935 the ten-year mean area irrigated was 49,153 acres with an average use of water of 1.42 acre-feet. The region which formerly was dry farmed grain fields had a population in 1930 of 75,865 people, including Burbank but excluding Glendale. Assessed values have increased from less than $10,000,000 in 1910–11 to $106,075,040 in 1931–32. As assessed values are but one-half of real value the enhancement due to putting water on the valley has in round numbers been about $200,000,000 dollars or about eight times the cost of the aqueduct. The higher domestic rate for water is applied as the character of its use is changed from irrigation. During April 1936, 243 new water connections were made in the valley, of which 201 were domestic. The lands are being at present largely subdivided into small farms of from 2 to 40 acres. They are being largely purchased by people of moderate means as country homes upon which the owners may raise much of their necessary food supplies and where they can work to an advantage when unemployed at their trades or professions. This is a feature of the modern industrial idea. A more

elaborate residential growth from Hollywood to Santa Monica has occurred since the advent of an adequate water supply to the previously dry area.

The conclusion is justified that the policy adopted by the Los Angeles City Water Board about 1912 for the use of the surplus waters of the Owens Valley is a demonstrated success.

Los Angeles City has grown in population from 319,198 in 1910 to 1,300,000 in 1936 and in assessed valuation between these two dates of from $276,801,517 to $1,298,647,285. The area of the city has increased from 90 square miles in 1910 to 451 square miles in 1931. The building of the Owens Valley Aqueduct and the policy adopted for the use of its water has largely contributed to these results.

The Owens Valley Aqueduct was built by day labor and within the estimated time and cost. It was designed to deliver 400 second-feet to the San Fernando Valley reservoir, but has an actual present capacity of 450 second-feet. It is 238 miles in length from its intake to the San Fernando reservoirs. It has been in operation 90.27 percent of the time, the remaining 9.73 percent being required for inspection, repairs and alterations. It therefore has an average capacity of 406 second-feet or 294,000 acre-feet per annum. In 1935 it delivered 68 percent of this capacity. The present city supply is sufficient to care for the requirements of 2,000,000 people plus the agricultural demand within its boundaries.

The present value of the Los Angeles Water Works in 1935 was $142,000,000. The department owns 281,342 acres in the Owens and Mono basins, including 89 percent of all the towns. The city has not condemned an acre of land or an inch of water in the Owens Valley. After deducting all charges including interest and depreciation the net revenue of the Water Department in 1935 was $1,501,670.

The Owens Valley aqueduct was designed to permit of the development of power. When it was nearing its completion a price was offered for this power sufficient to care for the fixed charges on the cost of the aqueduct. The municipality, however, decided to build its own power system which is said now to be the largest municipally owned power system in the United States. The net revenue of this bureau in 1935 was $4,060,503 after deducting all charges both fixed and operating. This is exclusive of the water revenues.

At the time the Owens Valley Aqueduct was constructed the record of the volume of flow of the Owens River was limited. In 1924 and in 1931 the flow of the major streams of the Sierra Nevadas fell to a

minimum of about 50 percent of any previously recorded discharge on both slopes and the surface runoff of the Owens River was found inadequate to meet the demand. It was found necessary to limit the irrigation of annual crops during 1923 to 1925, irrigation rights being secondary to municipal rights. The drought has been persistent since 1922. Resort therefore had to be made to wells in the Owens Valley to supplement the surface flows. During the past 18 years (1918 to 1935 inclusive) a total of 568,748 acre-feet were pumped from this source. Because of this situation and also as it was desirable to hold these groundwater sources for still more severe droughts should they occur in the future, it was decided to extend the aqueduct from the headwaters of the Owens River to the Mono Basin. This Mono project, involving the building of two dams, a 12-mile tunnel and a collection aqueduct, is now under construction. This is in no sense a new Owens Valley Aqueduct, but rather a supplemental supply for the existing aqueduct to be used during periods of drought and to maintain a full volume of water for all municipal uses, including existing power plants along the line of that aqueduct.

METROPOLITAN WATER DISTRICT

The problem of the Metropolitan Water District for the disposal of its surplus water while larger in scope is similar in character to that resulting from the building of the Owens River Aqueduct. It has been estimated that in the area which includes the habitable lands of the Santa Ana (exclusive of the Perris region) the San Gabriel and the Los Angeles river, amounting to 1,408,000 acres, the local water supplies plus that to be available from the Colorado River, amount to about 1,800,000 acre-feet per annum. This would provide 1.28 acre-feet per acre for the entire area. The District has the right to divert and is building an aqueduct to carry a million acre-feet per year or 1500 second-feet. Certain portions of this system, however, such as pumping plants and pressure pipe lines, are now being constructed to half capacity. Assuming a cost of $200,000,000 the debt to the people of its member units in 1930 was $120 per capita compared with $111 to the people of the City of Los Angeles, at the time the bonds for the Owens Valley Aqueduct were voted.

It was estimated in 1934 by the engineers of the Metropolitan District that the demand on this aqueduct is 1940 will be 195,500 acre-feet or 270 second-feet. Of this latter amount probably not over 100 second-feet will be required for immediate use within the present

boundaries of the member units of the District. There is, therefore, a large surplusage of water available for new member units consisting either of towns or agricultural communities organized as districts or for enlarged areas of member units. The adoption of a policy providing for the utilization of this surplus for irrigation at prices farmers can afford to pay is of the greatest importance to Southern California. The building of the Colorado River Aqueduct was a vital necessity because of the overdraft on the local groundwater supply upon which this region in greater part depends. Without the addition of some large new water supply this metropolitan area is already overdeveloped and cannot safely continue to expand. There is the ultimate necessity for all of the water of the Colorado River Aqueduct in this coastal region. Studies indicate that the shortage for habitable areas from Ventura to San Diego counties inclusive, above local supplies, is 2,000,000 acre-feet annually.

A problem of the Metropolitan Water District consists in the adoption of a proper plan providing for the prompt use of its surplus during early years of operation. Certainly no water should be placed on areas from which it should ever have to be withdrawn. Judging from the history of the Los Angeles Water Department and keeping in mind that the basic purpose in building both these aqueducts is the development of the region rather than profit from the sale of water, it is believed by the writer that the Metropolitan Water District can well afford to sell water for agricultural use at a rate that farmers can afford to pay. It would thus aid the development of the region and redound to the benefit of not only the farm land owners, but to labor, transportation, tax values and the commercial prosperity of the cities. The sale of water for irrigation during early years of operation is not merely an "incidental" feature of a proper policy. It is basic. If some such policy is not adopted the benefits resulting from this investment will be greatly restricted.

The acquisition of this large new water supply plus the great volume of cheap power from the Hoover Dam, for the metropolitan area, should and doubtless will continue the phenomenal growth of this region, in population and wealth.

ARTIFICIAL STORING OF GROUNDWATER BY SPREADING

By D. A. Lane

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"Water spreading" may be defined as the artificial replenishment of underground water bodies, or the artificial application of water upon the ground surface in such a manner as to allow the water to sink into and become a part of the underlying groundwater body. When compared with surface reservoirs, groundwater storage has many advantages. There is no loss by evaporation or transpiration, which is an item of considerable volume in surface reservoirs. It is less liable to contamination, and when infected it is usually confined to a small local area. Due to the large percentage of voids in most alluvial fills, the storage capacity is very large. In comparison with the acre-foot cost of most surface reservoirs, the underground storage cost is but relatively small. Water spreading is usually conducted by a governmental agency or a group of water users forming a cooperative association. Due to the area affected by the water spread, it is often very difficult to assess all parties benefited under a coöperative plan.

This venture has run the same gauntlet of most innovations. It was ridiculed at first as impractical and of no value, but was later accepted by most engineers and water works men of the Southwest.

Amateur conservationists and promoters became enthused and they contended that water spreading was the salvation of the semi-arid west; in their opinion it would supplement the need for flood control dams, obviate the necessity of importing water into southern California, and, in general, solve the entire water supply problem. This opinion later suffered a radical change and there are now many former advocates who are very firm in their belief that there is no benefit or value in any spreading program. However, unjust criticism has been made as a result of several installations which failed to function properly, due to lack of proper investigation and study of all the factors entering into the problem.

In order to spread with any degree of efficiency, the water must

contain the minimum amount of silt and colloidal matter. On streams without storage, this means that the peak of the flood must first be allowed to pass on account of the turbidity of the water. In most California streams, the quantity of water passing during the peak flow, and prior to the appearance of water sufficiently clear enough to spread, constitutes the greater percentage of the run-off. In many streams the water released from regulating reservoirs would be absorbed by the stream bed in its natural form; on such streams the construction of spreading works is obviously unnecessary.

Spreading may be used to accomplish several purposes, although its primary function is that of water storage.

STORAGE

Surface storage reservoir sites are rare, due primarily to the lack of safe dam sites. It has been remarked by local geologists, more in seriousness than jest, that a fault in southern California is a dam site. In the semi-arid southwest the problem of regulation by storage is of paramount importance to those responsible for a continuous supply of water, whether it be for domestic or irrigation use.

As a strictly storage measure, spreading may be considered as consisting of two sources of supply; that of local waters within the drainage area, and also waters imported from without the local watershed.

The selection of a spreading area is complicated by various factors, and may be comparable to the problem of a suitable reservoir location, in that a good dam site does not necessarily indicate a good reservoir site. In southern California the material eroded from the mountain areas is laid down in quite a characteristic manner. The coarser material is deposited at the canyon mouth and decreases in size as the distance from the mouth increases.

Before making any expenditure of money for the construction of spreading works, a complete study should be made of the percolation area together with all other factors entering into the problem. Test holes within and adjacent to the proposed spreading area will determine the presence of strata which might cause the building up of a groundwater mound, thus reducing the unit rate that the surface soil is capable of handling.

COST

On every débris cone there is a point of maximum spreading rate. This is the area containing the minimum amount of boulder and silt

material, and with the soil particles of nearly uniform size. In very few instances is it possible to spread on this area. Usually the soil is adaptable for agricultural or residential purposes and the price makes its purchase prohibitive.

Most of the spreading projects are located in districts where land values are at a minimum due to the soil not being adaptable for agriculture.

In any unit cost study, the first item to be considered should be that of construction. In common with many of our construction projects carried on during recent years, several spreading areas have been installed under some form of "Federal aid" labor. In most instances the manual cost, which amounts to practically the entire expense, has been furnished gratis to the water organization benefited. Unfortunately, such projects consummated under these methods are more favorable if the costs are not scrutinized too closely. While it is true that some spreading areas constructed with the "grant-in-aid" labor have little or no operating expense, however, if the carrying charges were considered they would be very costly.

VALUE

The question of value as applied to water is a subject of limitless discussion and particularly is this true in southern California. In many instances it is not what the water is worth, but to get it at any price. Within the interior foothill citrus area of Los Angeles, Orange and San Bernardino Counties, it is safe to assume that more than eighty percent of the total water used is from groundwater sources.

Many of the wells supplying orchards in the upper perimeter of the major valleys are pumping from isolated minor basins. During periods of normal rainfall these basins are maintained by streams which percolate sufficient water from their channels in the natural state. Periods of subnormal rainfall furnish stream flow only as flash flow peaks of a few days duration, which contribute little to the groundwater supply. If this water could be stored in control reservoirs and released as a regulated flow, it might be transmitted to the underground basins by means of spreading works. It would then be available to the many well diversions during the summer season.

With the exception of climate, the citrus industry is undoubtedly the most important contribution to southern California's prosperity. The two primary requisites of this crop are: an equable climate and an adequate water supply. In the arid southwest, by reason of the

unequal distribution of rainfall during the year the summer supply for citrus irrigation becomes a real problem. The original plantings were located in the vicinity of the canyons from which surface diversions were made; and due to the small amount of water available from this source in the late summer months, the area that could be served was limited. As the value of the returns from this crop were realized, the development of groundwater was begun, not only to supplement the surface supply, but to bring additional areas under cultivation. This development was naturally made in locations where the water was most readily obtainable with a minimum amount of lift.

This resulted in water and development companies concentrating their pumping in basins adjacent to the foothills and the concentration of pumping drew the water table down to alarming depths; these basins being, for the most part, isolated from the major basins in which they were located. It was utterly impossible for any of these companies to seek other sources of supply by reason of the amount of capital invested in wells and transmission lines.

The recharge of these isolated basins, either by the construction of spreading works, or flood control dams which would release a regulated flow to the stream channel and perform the same function, became imperative as during drouth cycles the water supply of the citrus industry is similar to that used for municipal purposes.

Therefore, it is not a question of the amount of the unit cost per acre-foot of storing water by this method, rather, is it feasible and will the water be available during the periods of below normal rainfall to those making the investment?

LOCATION

There is no general rule or plan which may be laid down as applicable to all groundwater basins. Each area must be taken as a separate problem and studied, not only from the possibility of artificial recharge, but also the effect upon the groundwater table and the ability to recover the water so spread. Recent tests have disclosed the fact that surface rates of percolation may not always indicate the proper type of spreading method to be used upon any given area. The application of water to the test area exhibited a high unit rate of percolation at first, but the continuance of the test revealed a less pervious subsurface stratum which retarded the downward movement of the water and forced it to escape laterally over a sufficient area of

finer and less permeable material to equal the addition from the surface percolation.

If reliance was placed upon the short period test, the investigator would have felt justified in the expenditure of funds on a type of spreading that would give a maximum surface area in contact with the water. The final result, however, proved that a more economical type of structure, although with less capacity, would in reality be sufficient.

If there is any question of the formations underlying the proposed spreading area and it is impossible to conduct percolation tests, a few test holes should be drilled and their logs carefully studied.

Wherever possible, groundwater elevations should be observed for the existence of possible submerged dykes. What might appear to be excellent spreading areas above groundwater storage basins are occasionally nullified by the presence of a groundwater barrier which forces the water to the surface, where it is subject to diversion, transpiration or evaporation losses.

A thorough study of the water plane of the groundwater storage basin, over a period of successive years prior to spreading operation, will prove invaluable to the engineer studying the problem of safe quantities to be spread annually.

RIGHTS

The conservation of water by storing it underground has an unfortunate disadvantage in comparison with surface storage. Surface stored water remains in place and possession, and may be withdrawn at any desired time. There is no question of the right to its use, or if so, the problem may usually be settled quite simply by legal means. The right to use is generally dependent upon possession, and when the water leaves the land and possession of an owner, all the right to and interest in it is gone.

Water artificially placed underground by spreading may possibly lose its identity and be withdrawn and put to use by anyone with a well located in its line of flow. Many times diverters may have no interest in the cost of the original water salvage, and in extreme cases may be in utter ignorance of the source of supply; other instances have occurred where diversions have been made by those located between the point of spreading and the diversion works of those paying the cost of salvage with full knowledge of the water's source.

The legal status of water spread has not yet been determined by the

courts; however, it would seem that when local stream waters are placed underground, they would be subject to diversion by overlying land owners. Likewise, there is no doubt that water spread can be recaptured before it leaves the land of the owner upon which it was placed. Where foreign, or imported waters are spread on formations overlying a subsurface stream, with the intention of using the subsurface stream as a carrier, the right of the importer to divert the quantity thus spread into the stream, less the transmission loss, cannot be seriously questioned as the rules governing subsurface streams are the same as for surface channels.

TYPES

There are three general methods of spreading practiced in southern California. The ditch or furrow method, the basin or pondage, and the use of wells or shafts. All three have modifications or variations and many times are used in conjunction with each other.

Furrow or ditch method

This plan of spreading is generally used in areas of very rough or sloping terrain and where the water at times may carry a heavy silt content.

Canals or ditches are laid out on contour with sufficient slope to prevent the deposit of the suspended material, yet flat enough to prevent scour of the channel. Due to variation of soils across the spreading area, the proper slope is often quite difficult of determination, yet may be corrected after construction by installation of check gates. Where only the canal beds are used for spreading, it is necessary to return a portion of the flow back into the stream channel from which the diversion is made in order to transport the silt out of the works.

A modification of the simple broad canal method is to install main canals, as broad as possible and with shallow depth, from which smaller ditches are led at regular intervals. From these smaller ditches the water is led out and spread over the ground, much in the same manner as flood irrigation.

Water not absorbed by the flooded area flows to the next lower main distribution canal, by which it is again distributed to a series of smaller ditches and their flooding area.

Advantages of the ditch method and its variations are the low cost of maintenance and operation when once correctly installed. When

the ditches are constructed so that the main channels may be flushed, this method will handle a greater silt content than any other type. An objection to this system is that the percentage of the total spreading grounds in contact with the water is very low, usually not over 10 or 12 percent.

Basin method

The most simple form of the basin method is the construction of dykes or small dams at regular intervals across the natural abandoned channel on a débris cone. The water is led into the upper basin by means of a canal and from this point, as each basin fills, it spills to the next one, until when the last on the line is passed the waste water is returned to the flood channel. The upper basins serve as desilting ponds and prevent excessive colloidal material from being deposited in the lower structures.

On some projects the water that passes through the system of basins is spread by a canal or irrigation system. This permits the diversion of water during periods when the stream is carrying more silt than could be handled direct by a canal system.

Some projects divert water from local streams by means of temporary dams into basins constructed by throwing up earthen dykes. These basins vary in size, depending on the slope of the land and are not leveled.

Each basin, as it fills, spills to the next in the series, the overflow from the area being returned to the stream.

The native grasses and shrubs are allowed to remain undisturbed and apparently have a very beneficial effect on the percolation rate.

Operating cost on this type of works is limited to installation of the diversion dam and patroling the dykes for leaks caused by burrowing rodents.

In the San Fernando Valley, underground storage is utilized by the spreading of imported Owens River water in abandoned gravel pits and by the basin method.

After three years of tests the basin type was adopted as most suitable to meet all conditions, one of which requires absolute control of the water with no waste flow. Due to land values, the method used had to obtain the maximum area in contact with the water.

Basins average 100 by 400 feet, with a depth of 3 feet. Each basin is fed by a 6-inch pipe line laid in the center and controlled by a valve

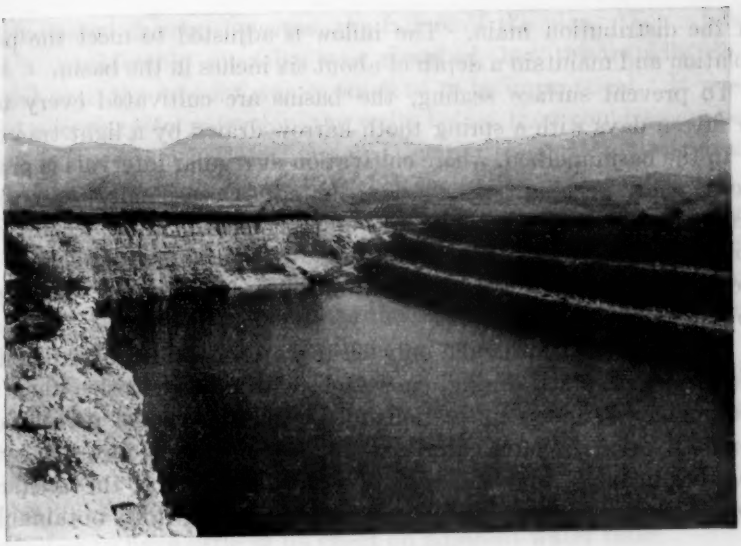

FIG. 1. GRAVEL PIT SPREADING SAN FERNANDO VALLEY, OWENS RIVER WATER, VIA LOS ANGELES AQUEDUCT

FIG. 2. PORTION OF LOS ANGELES WATER BUREAU SPREADING GROUND, SHOWING CULTIVATION

Water depth maintained to depth of 6-inches. At left is inlet line. House in center background is Venturi meter recorder.

at the distribution main. The inflow is adjusted to meet the percolation and maintain a depth of about six inches in the basin.

To prevent surface sealing, the basins are cultivated every ten or fifteen days with a spring tooth-harrow drawn by a light tractor.

In the basin method, where cultivation at regular intervals is practiced, many peculiarities have been noted. Occasionally the entire area will have an increase in the unit percolation rate, which will continue to accelerate for several days. With no apparent change in weather, temperature of air or water or soil surface, the rate will begin to decrease.

While designed to handle only clear water, considerable colloidal material was spread during one season, with no effect other than to require more frequent cultivation and a lower unit rate of percolation for that period. Water entering the spreading area is recorded by a Venturi meter. All basins are observed hourly and the area recorded, thus the unit rate for any period of time is readily obtainable.

Wells and shafts

Wells and shafts have been used by several agencies as a means of putting water under ground with varying degrees of success.

As a general rule, spreading by this means is applicable only in those localities where the ground surface and the water-bearing formation are separated by clay or cemented materials, which prevent the free downward percolation of water from surface spreading works.

Several agencies spread a small amount of water by means of shafts and wells in conjunction with their surface spreading or in adjacent areas where underlying strata make their use necessary. There has been no project developed entirely dependent on this type of water application. This is due primarily to the tremendous expense in the installation of wells and shafts.

A few years ago, an attempt was made to use a group of wells in the San Fernando Valley to spread clear imported water. These wells were 20 inches in diameter with an average depth of about 400 feet through a coarse granitic alluvium. All were excellent wells, operating at an average of 5 second-feet per well and producing considerable more on test. The normal water table was from 90 to 100 feet below the ground surface.

No measurements of absorption by individual wells, or total quantities, were obtainable due to direct diversion from the distribution mains through the pumps. The operation of the gates at each

well indicated clearly, however, the failure of the plan. For a few days a considerable quantity was absorbed, but this rapidly decreased until the amount was so small as to be impractical. It was found necessary to redevelop the wells before they could again be placed in operation. Unfortunately, this particular test, through a misunderstanding, has been reported as successful.

This decrease in rate is due primarily to the rearrangement of the soil particles as a result of the reversal of the direction of flow. Under pumping conditions, the smaller particles flow into the well and are removed. In spreading operations the disturbed soil moves into the interstices of the formation, tending to seal it off.

The disturbing effect of the reversal of flow in water mains is well known to all water works men, as evidenced by the silt content of the first water obtained from many fire hydrants.

Unfortunately, most data on this type of spreading are for short periods of operation, usually on isolated wells, and the quantity spread so small as to have little or no effect on adjacent water table.

A test on two types of wells in the coastal plain of Los Angeles over a three year period indicated that the percolation rate was a direct function of the head maintained above the normal water table.

It also revealed that the spreading rate is a very small percentage of the pumping capacity. One of the wells had a spreading capacity of only 16 percent of its two second feet pumping capacity.

Stream channel spreading

Some form of stream channel spreading is practiced on most major streams in southern California.

All of these streams are subject to flash flows of short duration, but of large volume. On the lower valley areas this results in a broad flat sandy bed which is dry during the summer months and during winter months has a surface flow covering but a small portion of its area.

For several years conservation associations and county agencies have diverted the streams in these areas and spread them by various systems. Where the stream channels are composed of materials that tend to consolidate and seal off, the stream bed is broken up by tractors dragging cultivators.

In flat sandy stretches furrows are plowed and the stream diverted into them. Temporary basins are also constructed by furrowing machines on these flood plains.

The value of spreading in these lower areas is twofold in that it prevents water from running to waste into the ocean and distributes it to storage basins that receive little or no benefit from spreading on the débris cones. On some streams, to prevent litigation, it has been necessary for operators of débris cone spreading works to divert water only when it would otherwise pass these lower spreading areas.

A variation of spreading by temporary ploughing and cultivating in the stream channel is the construction of permanent structures across the entire channel. This structure spreads the stream flow out into a thin sheet and increases the percolation by the increased area in contact with the water.

A single structure was constructed in this manner on a stream several years ago by a Water District. On several occasions it has reduced the flood flow peak as much as 70 to 80 percent. Another stream, when it leaves the mountain canyon, passes through a broad alluvial bench through which it has erroded a channel several hundred feet wide. Spreading on this stream is artificially increased by the construction of low dams across the channel at regular intervals, which force the peak flows to pass in a thin sheet over the entire channel, rather than concentrate and scour. There are sufficient dams to handle any flow but a major flood, and even that would be considerably reduced in quantity.

These structures require little or no attention to operate. The installation cost, however, was so great that had they not been put in as "Federal Aid" project, those benefited could never have financed it.

UNIT RATES OF PERCOLATION

Up to the present time, with few exceptions, unit rates of percolation for spreading projects for an entire season are not available.

Test areas and short run rates are given for most localities, but they are proven very unreliable when compared with seasonal rates for a large area.

In the past, the lack of information was due primarily to lack of measuring devices and secondly, to the impossibility of even estimating the area in contact with the water. The Bureau of Agricultural Engineering of the Department of Agriculture has installed measuring flumes and recorders on many of these spreading areas to obtain more definite information on this subject. The area covered will still be a matter of conjecture through the season, being dependent on the estimating ability of those in charge of operation.

Published unit rates on various southern California streams vary from 2.74 to over 16 acre-feet per acre per day. These figures, of course, are not seasonal averages and are for small areas only.

The clean cultivated basin method has varied from 5.51 to 6.92 with 4 year seasonal average of 6.20 acre-feet per acre per day.

All areas have an initial starting rate that may be five times as great as the normal percolating rate. This initial rate does not last more than a few days, after which the decrease is quite rapid, until the normal rate is reached, which continues with but slight variation for a considerable period of time.

EXPERIMENTAL WORK

Supplementary and additional lines of investigation have been initiated by governmental and private agencies to bring about the most complete and economic types and methods of spreading.

The Bureau of Agricultural Engineering has devoted considerable time and effort to this phase of the work with excellent results. It is also serving as a clearing house through which other interested agencies may work and compare results.

A recitation of all the activities would draw attention to the important place which the matter of water supply has reached. It is stated, by investigators of the subject, that the increasing demand will make it imperative to save all local supplies, whether it be done by flood control, sewage reclamation or the importation of water from without the local watershed; the principal difference in views being as to when this will be necessary and as to the most economic solution.

The spreading of water over absorptive areas for underground storage is still in its infancy and there are many things occurring during the operation of the various plants to which the answer is unknown at the present time.

CONCLUSIONS

Water spreading has a definite place in the water supply of the Southwest. It is not a cure-all, and the problem should be carefully analyzed before a spreading program is commenced. Depending upon the location, duty it has to perform, and economy of operation, it may be adapted to many areas, and in particular to those basins in which the longtime natural recharge does not equal the demand for extraction.

SOME RECENT FEDERAL ACTIVITIES IN THE CONSERVATION OF WATER RESOURCES

By Abel Wolman

(Chairman, Water Resources Committee, National Resources Committee, Washington, D. C.)

Over 35 individual agencies of the Federal Government are concerned with water resources activities. The interests of the Federal Government, therefore, in the use and control of water are complex and highly diversified. In the Department of Agriculture, some 7 agencies; in the Department of Commerce, 4 agencies; in the Department of the Interior, 8; in the State Department, 2; in the Treasury Department, 2; in the War Department at least 3 and in various independent and financing departments, 10 agencies have direct and important interests in the control and use of water.

Federal expenditures for the use and control of water resources have expanded greatly in amount and in scope during the past 16 years. During the last 5 years, of course, the rate of expenditures has been multiplied tremendously.

During the period of 1920 to 1929, annual Federal expenditures for construction involving water use and control ranged from 30 to 63 million dollars In the fiscal year 1929, the expenditures increased to a new high of 78 million. By 1932 they had risen to 108 and by 1935, to 374 million dollars. Construction of water projects during 1935 reached a volume, therefore, more than 12 times as great as that of 1922. The figure for 1935 is probably lower than the actual expenditure because water works construction under the Federal Emergency Relief Administration and the Civil Works Administration is not included. No detailed breakdown of construction expenditures under the supervision of these organizations was available for the purposes of this paper. The details of these expenditures are shown in tables 1 and 2.

The relation of water use and control expenditures to Federal construction expenditures as a whole remained roughly the same throughout the period. Water projects accounted for 36 percent of Federal construction in 1924, and for only 19 percent in 1922, but

for the most part they ranged from 20 to 30 percent of the total (tables 1 and 2), and that proportion held true even during the recent years of public works expansion. Under both normal and emergency conditions during the last sixteen years water projects accounted for an average of one-quarter of Federal construction.

TABLE 1

Federal construction expenditures for all purposes compared with expenditures for water use and control 1920–1935

(In thousands of dollars)

FISCAL YEAR	DEPARTMENTAL		EMERGENCY†		DEPARTMENTAL AND EMERGENCY COMBINED	
	Water	All purposes*	Water	All purposes	Water	All purposes
1920	43,100	146,417			43,100	146,417
1921	44,161	172,245			44,161	172,245
1922	30,285	160,715			30,285	160,715
1923	39,265	142,358			39,265	142,358
1924	60,332	168,526			60,332	168,526
1925	63,816	205,305			63,816	205,305
1926	48,126	175,159			48,126	175,159
1927	41,424	174,039			41,424	174,039
1928	51,157	188,519			51,157	188,519
1929	62,176	221,136			62,176	221,136
1930	78,923	250,899			78,923	250,899
1931	99,963	394,768			99,963	394,768
1932	110,074	473,848			110,074	473,848
1933	111,837	460,575	20,355	89,117	132,192	549,692
1934	62,054	269,526	171,851	828,497	233,905	1,098,023
1935	20,815	126,719	354,909	1,240,022	375,724	1,366,741

* Modified slightly from data published by the Federal Employment Stabilization Office.

† Includes Emergency Conservation Work, Reconstruction Finance Corporation, Public Works Administration. Expenditures not available for Federal Emergency Relief Administration or Civil Works Administration. All R F C figures are disbursements and the total construction figure for this agency is approximate because industrial loan disbursements cannot be broken down accurately. E C W data for 1935 are for the first 9 months only.

Although the ratio of water construction to all Federal construction did not change under the stimulus of the emergency program, the ratio of water construction to the total United States construction altered notably. From 1925 to 1929 Federal water projects constituted a bare one-half percent of all construction in the country.

After 1929, with the steady decline in private construction, and with the sharp rise in Federal construction following 1932, water projects assumed greater national significance. By 1933 they comprised 4.6

TABLE 2

Federal construction expenditures for water use and control compared with federal and estimated total United States construction for all purposes 1925–1935

FISCAL YEAR	FEDERAL WATER	FEDERAL ALL OTHER PURPOSES	ESTIMATED PUBLIC NON-FEDERAL	ESTIMATED TOTAL PRIVATE UTILITIES	ESTIMATED TOTAL PRIVATE CONSTRUCTION	ESTIMATED TOTAL CONSTRUCTION
			Millions of dollars			
1925	63	205	2,470	2,840	5,240	10,819
1926	48	175	2,380	2,990	5,630	11,223
1927	41	174	2,800	2,980	5,240	11,235
1928	51	188	2,750	2,960	5,490	11,439
1929	62	221	2,480	3,340	4,610	10,713
1930	78	250	2,920	3,290	2,800	9,339
1931	99	394	2,410	2,250	1,810	6,964
1932	110	473	1,490	1,360	680	4,113
1933	132	549	1,500	1,050	750	3,981
1934	233	1,098	1,030	1,190	870	4,421
1935	375	1,366	1,030	1,230	990	4,992
Total....	1,297	5,098	23,260	25,480	34,110	89,245
			Percentage of total United States			
1925	0.59	1.90	22.8	26.2	48.1	100
1926	0.42	1.56	21.20	26.64	50.16	100
1927	0.37	1.55	24.92	26.52	46.63	100
1928	0.44	1.64	24.04	26.04	47.99	100
1929	0.58	2.17	23.14	31.17	43.03	100
1930	0.84	2.68	31.26	35.22	29.97	100
1931	0.14	5.67	34.60	32.30	25.98	100
1932	2.66	11.51	36.21	33.05	16.52	100
1933	3.32	13.80	37.70	26.40	18.80	100
1934	5.29	24.80	23.30	26.90	19.67	100
1935	7.53	27.40	20.60	24.60	19.83	100

The totals exclude maintenance, and the construction of pipelines, telegraph lines, gas works, and water works by private utilities.

percent of all construction, and had arisen to approximately 9 percent by 1935.

The increase in amounts expended after 1932 may be ascribed

wholly to the addition of funds for emergency purposes. Allotments under the regular departmental budgets fell to less than 20 million dollars in 1935, at the same time that the allotments under emergency acts rose to 354 million. Thus, although the source of funds changed, and the total expenditures mounted under emergency conditions, the relative importance of water projects in the Federal budget remained the same.

Two agencies, the Corps of Engineers and the Bureau of Reclamation, supervised the greater portion of all water projects undertaken by the Federal Government in normal times. In the thirteen year period preceding 1935, more than 95 percent of the annual expenditures were allotted to these two organizations. Except in 1928, when allotments to the office of Indian Affairs exceeded 4 million dollars, the irrigation work of the Bureau of Reclamation and the flood control and river and harbor improvements of the Corps of Engineers accounted for at least 93 percent of all such Federal expenditures each year.

The Indian Office, the Forest Service, the Bureau of Fisheries and the Geological Survey each received allotments quite small in comparison with the two aforementioned agencies.

In the years following 1932, the expenditures for rivers and harbors and for the Bureau of Reclamation mounted through the use of Public Works Administration funds. The amount of work supervised, however, by other established Federal agencies was not changed markedly. The great increase in expenditures was made under the supervision of new agencies,—The Tennessee Valley Authority, the Emergency Conservation Work, the non-federal projects of the Public Works Administration and the Reconstruction Finance Corporation. By 1935, more than one-quarter of Federal expenditures for water projects were being supervised by States, counties, municipalities or private corporations. No estimate for the expenditure made under the Emergency Relief appropriations by state and county relief organizations is available, although it is known that at least 6 million dollars were spent by these agencies for water conservation projects in the drought states during 1934.

During the 16 year period under discussion, progressive diversification of Federal water resources work has occurred. In 1920 river and harbor improvements constituted approximately three-quarters of all Federal expenditures. Irrigation and flood control work accounted for the greater part of the remainder. A relatively slight

amount was spent for fish ponds and hatcheries, for new stream gaging stations and for stock water development on the public domain.

In 1935 an entirely different picture of relative allocations appears which may be of considerable national significance. Navigation and flood control work had grown to far greater dimensions. Irrigation had increased to a lesser degree, but the dominance of these activities in the Federal construction field had been lost. Wild life and recreational projects had gained in importance. The most significant changes were the additions of municipal water supply, sewerage and sewage treatment and multiple purpose projects. The last group represented Federal undertakings designed to serve more than one use with the development of hydroelectric power as perhaps the most common of the multiple uses and exemplified in such projects as Boulder Dam, Bonneville, Grand Coulee, Norris Dam and Madden Dam.

These changes in nature and amount of Federal expenditures are of great national significance and raise new problems of water resources allocation and financing. Many new supervisory agencies entered a field previously dominated by two established units and for the first time in the history of this country, a substantial part of the work undertaken by municipalities or other local agencies was carried out with the financial assistance of the Federal Government and with varying degrees of Federal supervision.

Many people interested in the problems of water resources of the nation have been perhaps unaware of these profound changes in the engineering, administrative and financial structures of the water resources field. Even in the rush of emergency enterprises due to the depression, the importance of these changes, however, are apparent to some. The reports of the Mississippi Valley Committee and of the Water Planning Committee of the National Resources Board were indices of an awakened national interest in the tremendous problems of the use and control of water resources. A rational and orderly development and use of these resources has become more and more of a necessity as extension of operations in this field has occurred. The emphasis on the drainage basin of a river as the unit for study of water problems has increased. The search for a coördinated unified water policy was initiated and is still the subject of much discussion. The promotion of public health, of public safety, of convenience and comfort, of the economic welfare and of reconciliation of water use

with land and mineral conservation offer new fields for thought and criticism whose importance can no longer be submerged.

Even the adoption of a water plan for the river basin resting solely upon hydrological studies is no longer considered to be completely adequate without a corresponding study of the inter-related cultural and physical problems of the basin.

Opportunity to provide for continuing modifications and adjustments of long range programs for any drainage basin area, so as to avoid haphazard and even excessive expenditures, presents a field for thought for those interested in water resources.

When we pass from these activities into the realm of determining the cost of executing the plan and the distribution thereof among the various groups concerned, in accordance with the distribution of benefits, the complexities of the situation are immediately apparent. The evaluation of indirect and intangible factors and advantages, in comparison with estimated costs and tangible benefits, present issues which cannot be decided on the spur of the moment and in the heat of public discussion.

The axioms that the most beneficial use of water resources of any valley should be related to the development of other physical resources, that development of any one phase of water resources should be considered in relation to all other phases, that physical factors are of importance in relation to cultural and economic conditions and that present as well as future aspects should play a part in any program, must lead to the conclusion that competent administrative authority over water use and control is necessary for the determination of the most equitable allocation of uses.

The establishment of the Water Resources Committee of the National Resources Committee is therefore the natural result of a series of events of the last 5 or 6 years of our operations in this country. Under the pressure of emergency expenditure, important activities in the field of water use and control gave rise to the Mississippi Valley Committee and to the Water Planning Committee. The report of the Mississippi Valley Committee presented a broad policy of water development in one of the largest areas of the United States and that of the Water Planning Committee a rapid inventory of the present resources and data. The creation of the Water Resources Committee was intended to carry forward the activities of the previous committees in the coördination of Federal and Federal-local activities in water planning and development, the collection of basic

hydrological data, the regulation of conflicts of interest or purpose, the extension of basic information, the development of drainage basin economies and, as a natural result thereof, the promulgation of works priority lists which would fit into the gradually crystallizing pattern of drainage basin economy.

ORIGIN AND PERSONNEL OF THE WATER RESOURCES COMMITTEE

The Water Resources Committee was organized on July 24, 1935, as the successor to the former Water Planning Committee of the National Resources Board. It now constitutes the agency of the National Resources Committee which deals with water resources.

The Water Resources Committee consists of twelve members, three from the former organization, and nine new members. Eight Federal agencies, and two State agencies are represented. The eight representatives of Federal agencies were selected upon the basis of the specialized knowledge and official responsibility in the field of water resources of the agencies represented. The State representatives were selected partly upon the basis of the importance of the water resources problems in their States and partly upon the qualifications of the individuals whose services in this capacity could be secured. The two remaining members were selected from consultants whose connection with the former committee had established their special qualifications and given them familiarity with the prospective work of the present committee. The membership of the committee is therefore well suited to the work which it is to do. It has the following personnel:

H. H. Barrows, Chairman, Department of Geography, University of Chicago.
H. H. Bennett, Chief, Soil Conservation Service.
Ira N. Gabrielson, Chief, Biological Survey.
N. C. Grover, Chief Hydraulic Engineer, U. S. Geological Survey.
Edward Hyatt, State Engineer of California.
Edward M. Markham, Major General, U. S. A., Chief of Engineers.
John C. Page, Acting Commissioner of Reclamation, Bureau of Reclamation.
Thorndike Saville, Dean, College of Engineering, New York University.
R. E. Tarbett, Sanitary Engineer, United States Public Health Service.
Thomas R. Tate, Director, National Power Survey, Federal Power Commission.
Sherman M. Woodward, Chief Water Planning Engineer, Tennessee Valley Authority.
Abel Wolman, Chief Engineer, Maryland State Department of Health, *Chairman*.

An Executive Committee of four, two Federal and two non-Federal representatives, acts as a steering committee to shift such burdens of detail as it can from the whole committee by advance consideration of complicated questions, to dispose of minor matters not regarded as worthy of consideration in advance by the whole committee, and to act in any emergency when time may not permit the entire committee to assemble.

Inasmuch as the primary duties of the Committee are those of coöperation and steering, the continuation and reorientation of water studies by close contact with other Federal agencies, the Committee's object should generally be achieved through those Federal agencies and should not require the creation of a large and expensive headquarters staff. Temporary consultants and other assistants are utilized in special situations without adding new permanent employees. The work of the Committee itself which will be described in greater detail below, has been directed primarily towards the development and application of the best opportunities of water planning, even when dealing with special or local problems in that field.

COLLECTION OF BASIC INFORMATION

The former Water Resources Section organized a Special Advisory Committee on Standards and Specifications for Hydrologic Data, composed of representatives of Federal agencies which collect such data and representative engineers who use them in private practice. The members of this Special Advisory Committee are:

Donald M. Baker, Consulting Engineer, Los Angeles, California.
H. K. Barrows, Consulting Engineer, Boston, Massachusetts.
J. P. Dean, Captain, U. S. Corps of Engineers.
Willis R. Gregg, U. S. Weather Bureau.
N. C. Grover, U. S. Geological Survey.
W. W. Horner, Consulting Engineer, St. Louis, Mo.
Joseph Jacobs, Consulting Engineer, Seattle, Washington.
Royce J. Tipton, Consulting Engineer, Denver, Colorado.
Thorndike Saville, Dean, College of Engineering, New York University, New York, N. Y., *Chairman*.

The first report of that committee has been published and distributed under the direction of the Water Resources Committee. It was concerned primarily with the establishment of standards for the collection of hydrologic data through Works Progress Administration projects under the relief program, but it included the establishment of standards which are of broad application and permanent

value. The personnel requirements established for projects under the relief program have not permitted the adoption of data collection projects as extensively as had been hoped. Such projects were, however, approved and put under way in the States of Vermont and Massachusetts, in the Connecticut River Basin, and this activity is attributable in part to the support of the Water Resources Committee.

A nation lacking basic information on its water resources cannot hope to make the most effective use of them. Sound practice in the design and construction and operation of water use and control works is determined in large measure upon reliable hydrologic data. Without them, large amounts of Federal and private funds have been expended repeatedly in the past. Some irrigation and hydroelectric power projects have been carelessly planned. Damages to private property from floods and droughts have been unnecessarily great. Drainage projects, highways, railways and other structures have been damaged or destroyed by flood flows the prediction of which was impossible in the absence of long term records.

On the other hand, some projects may be overbuilt in order to provide a factor of safety which might have been scaled down if a reasonable amount of information recording minimum and maximum conditions in the past and the probability of their recurrence in the future had been at hand. Losses of similar character will occur again in the future as long as the deficiencies in our knowledge of water resources remain uncorrected.

The special advisory committee mentioned above has made an inventory of all hydrologic data collecting work now carried on by Federal agencies, independently or in coöperation with state and local interests. It has reviewed that work from the standpoint of engineers, farmers, water works and power plant operations, and others who use such material. In its previous report on hydrologic standards it had pointed out certain immediate deficiencies. In the light of this previous investigation and of its present experience, a number of extensions and modifications in the present hydrologic data collecting activities of Federal agencies are proposed as essential prior bases for the efficient development of the nation's water resources.

Among other things it recommends:

1. The improved inspection and rehabilitation of existing precipitation stations. The publication of hitherto unpublished

precipitation records. The establishment of over 1200 new cooperative rainfall stations in localities where rainfall is not now measured. The establishment of 6 new first order meterological stations in high altitudes. The establishment of 400 recording rain gages to collect data on intensity of rainfall.

2. The establishment of at least 500 snow survey courses in mountain areas to improve the forecasting of stream flows along major Federal water conservation projects and privately irrigated lands.

3. The establishment of 500 Federal base stream gaging stations and of 600 coöperative secondary stations and the rehabilitation of 1000 old stations.

4. In order to expand the information on the extent and fluctuation of ground water through the United States, the installation of 4000 Federal wells as base stations, of 6000 coöperative secondary wells and of corollary geological and hydrological investigations, is recommended.

5. Evaporation data should be made available by the establishment of 30 first class stations and 250 second class stations, by the compilation of all unpublished data, and by research on the solar energy method of evaporation, and on evaporation from snow and ice surfaces.

6. Data on the quality of surface waters should be collected systematically at 200 Federal base observation stations and 400 cooperative secondary stations.

The Committee has drawn a clear distinction between work which should be carried on by the Federal Government alone in order to secure continuous records at a few strategically located base stations and that which should be contingent upon 50–50 coöperation by local and state agencies.

The total cost of the program recommended for the correction of important deficiencies in our knowledge of water resources would be insignificant in comparison with the savings made and the potential damages averted.

RESOLUTION OF CONFLICTS OF INTEREST OR PURPOSE

Regardless of controversies as to the relative spheres of action of Federal and state agencies, one of the first problems confronting any group interested in adequate water resources control and use is that of coördinating the conflicting purposes and methods of both Federal and state agencies. No one believes that the Federal Government

will or can ever withdraw completely from water supply activities. With this definite prospect in mind, attention necessarily must be directed to eliminating as far as possible such conflicts of interest or purpose which may arise within or between Federal agencies. When the study of such conflicts is undertaken it is soon apparent that the effects thereof are not restricted by any means to the Federal agencies. The repercussions and results of conflicts in interest and in purpose of Federal agencies are transmitted almost instantly to the lower levels of Government, whether state, municipal or county.

Drainage and water storage

Because of the intensification of some of these conflicts in recent years, due primarily to vast expenditures by emergency agencies, the Secretary of Agriculture on August 9, 1935, requested the National Resources Committee to review the operations of some 12 to 14 Federal agencies with a view to determining the character of their land drainage and water storage programs and methods, with particular reference to wild life, pest control, malaria control and reclamation. This request was made by the Secretary of Agriculture largely because of the fact that some serious difficulties had arisen through the failure of some agencies to reconcile in advance some of their differences with other agencies in these major fields of operation.

The Water Resources Committee, therefore, on October 29, 1935, appointed a special sub-committee on Drainage Policy and Projects to report on the question. The members of this sub-committee are:

W. B. Bell, Bureau of Biological Survey.
Lt. Col. Glen E. Edgerton, Office of Chief of Engineers, U. S. Army.
Perry Fellows, Works Progress Administration.
Elmer Higgins, Bureau of Fisheries.
S. H. McCrory, Bureau of Agricultural Engineering.
S. A. Rohwer, Bureau of Entomology and Plant Quarantine.
P. I. Taylor, Bureau of Reclamation.
L. L. Williams, U. S. Public Health Service.
Abel Wolman, *Chairman.*

To this sub-committee comprising representatives of 9 interested Federal agencies was delegated the task of considering the nature of drainage work in which the Federal Government is now engaged, the conflicts of activity which have arisen among both Federal and state agencies with respect to drainage and the formulation of a plan

whereby the program of work of the various agencies might be currently reconciled in order to eliminate conflicts and to increase the general advantage of each program.

This sub-committee made its report on January 14, 1936, finding that conflicts of Federal activities in drainage and storage work, resulting in unnecessary waste and delay, have occurred; that the number of such conflicts may be expected to increase as a result of recent extensions of Federal authority over drainage work and that all but a few of the conflicts might have been prevented had there been an opportunity for reconciliation of policies during the planning of the various programs. The Committee recommended an administrative mechanism for promotion of balanced consideration of proposed Federal projects and for reducing friction and delay in their execution. Similar findings and recommendations were made as to projects for impounding water, since the study of these projects disclosed similar opportunities for smoother administration.

Inasmuch as the mechanism suggested for coördination and reconciliation required authority for the National Resources Committee to serve as a clearing house of information and opinion concerning proposed Federal drainage and water storage programs, the President issued an order to existing Federal agencies concerned with projects or allotments for land drainage or water storage, on February 1, 1936. He instructed the appropriate officials of every Federal agency concerned with projects or allotments for land drainage or water storage to submit a statement of impending programs of such work to the National Resources Committee at regular intervals in order that other agencies having an interest in the work may be informed by the Committee of the programs well in advance of their initiation.

As a result of this Presidential order, monthly reports on impending programs of land drainage and water storage are prepared with the coöperation of the various Federal agencies by the Water Resources Committee and are circulated among all of the interested agencies.

Some impression of the extent of such impending programs and of the complexities involved in adequate interchange of information among Federal agencies may be gained from the fact that the second monthly report issued on April 1, 1936, by the Water Resources Committee on this particular subject, included over 2000 land drainage and water storage projects sponsored for ultimate execution by Federal agencies. In the first monthly report of March 1, 1936, even a greater number was listed.

It is apparent after only a few months operation of the machinery, that this effort at coördination is proving highly successful. Very few conflicts should ultimately reach the Water Resources Committee for adjudication. As was anticipated by the sub-committee on Drainage Policy and Projects, by far the greater number of conflicts are settled by representatives of the individual agencies as soon as they are made aware, by circulation of the monthly lists, of the possibilities of interference.

This particular enterprise illustrates the vast problem in Federal operations of reconciliation and coördination of policy, activities and procedures. At the moment, no staff organization is or has been available to the President or to Congress whose sole purpose it is to review, sieve and reconcile the purposes of Federal agencies. In theory, perhaps, meetings of the Cabinet were intended to provide this functional review. For obvious reasons busy cabinet officers cannot subject the individual undertakings to careful technical review and for even more obvious reasons it is doubtful whether reconciliation of purpose can be accomplished through independent cabinet officers representing specific Federal agencies. Some kind of continuing staff organization apparently is essential to provide the President and Congress with recurring reviews and recommendations regarding the operations of individual Federal agencies. Such continuing staff review is wholly independent of the question of reorganization of existing Federal agencies and need have nothing whatever to do with policies of expansion or contraction of agencies. With the knowledge that, whatever the agencies, conflicts in water use and control are likely to occur in the great undertakings of the Federal Government and in their relation to State interests, it is clear that some permanent mechanism must be established which can subject the policies and procedures to recurring and continuous review by groups somewhat independent of the current administrative restrictions.

Water pollution

A second activity of the National Resources Committee to which attention should be directed, is the report of the Special Advisory Committee on Water Pollution, issued in September, 1935. The members of this Special Advisory Committee are:

W. B. Bell, Bureau of Biological Survey.
Lt. Col. Glen E. Edgerton, Office of Chief of Engineers, U. S. Army.

A. C. Fieldner, Bureau of Mines.
Elmer Higgins, Bureau of Fisheries.
Thorndike Saville, Dean, College of Engineering, New York University.
R. E. Tarbett, Sanitary Engineer, U. S. Public Health Service.
Abel Wolman, Chairman, Water Resources Committee, National Resources Committee.

This sub-committee was appointed by the Water Resources Section of the National Resources Committee, the agency which preceded the Water Resources Committee. The increasing importance of water pollution by domestic and industrial waste led the National Resources Committee to request a review of the legal, public health, biological, industrial and financial aspects of this difficulty. As half a century ago navigation was perhaps the most important consideration in the public eye with respect to rivers, so in recent years water pollution is gaining more and more importance in public discussions and in efforts towards regulatory control. The Special Advisory Committee on Water Pollution which was appointed in December, 1934, completed its deliberations and submitted a report on May 3, 1935.

Through the Surgeon General of the U. S. Public Health Service, Sanitary Engineer H. R. Crohurst of the Cincinnati Station was assigned to the Committee to assist in the collection and analysis of pertinent data on the subject. State health, conservation and fish and game agencies supplied additional material. The joint committee of the American Society of Civil Engineers and of the American Institute of Chemical Engineers presented important material with respect to the treatment of industrial wastes. The status of standards as applied to water pollution was carefully reviewed for the Committee by Mr. H. W. Streeter of the U. S. Public Health Service, while Dr. M. M. Ellis of the U. S. Bureau of Fisheries gathered information on water purity standards for the maintenance of aquatic life.

The consolidated recommendations of the sub-committee are reproduced herewith:

"Any program of water-pollution control should include agencies of the Federal and State Governments that are concerned with the matter and the branches of industry that are responsible in part for pollution or are seriously affected by it. An important detail of such a program involves the inclusion, in the control organization, of regional authorities, metropolitan districts, or local abatement districts, for the comprehensive coördination of control

work. To date, agencies of this nature have entered into such control to only a limited extent."

The Committee recommended the following policy in relation to water-pollution control:

"1. That where drainage area authorities exist for the comprehensive development and control of water, their scope be made sufficiently broad to include control of pollution.

"2. That no basic changes in existing Federal law with reference to water-pollution control be made until the experimental program presented later herein shall have indicated whether or not such changes are desirable and feasible.

"3. That simplification and coördination of State laws be affected to provide for the following minimum requirements:

(a) Adequate administrative control.

(b) Delegation to the administrative agency of power to determine the nature and extent of pollution prohibited by the statutes, and to establish limitations of pollution.

(c) Appropriate mandatory powers, particularly the power to compel the installation of essential remedial works and force other necessary action.

(d) No limitation on the taxing or bonding power of municipalities, when applied to remedial works ordered by the administrative agency.

(e) Power to require facilities through sewerage districts, sanitary districts, or otherwise, that will enable municipalities and industries to comply with the law.

"4. That broader authorization for research be granted to those agencies of the Federal government which are already concerned with various phases of the problem, and that adequate funds be provided for properly coördinated water-pollution investigations.

"5. That powers and funds be granted to an appropriate Federal agency to institute a coöperative program of investigation with legally constituted State agencies for such special studies as appear desirable, and particularly for the development of appropriate standards for water use and control.

"6. That in order to stimulate the construction of pollution-abatement works, funds for the purpose be made available by the Federal government to local public and private agencies on a grant-in-aid or loan basis. Lacking any precedent for the designation of appropriate bases for such allocations, the Committee recommends the creation of a demonstration unit on a river system selected for that purpose.

"Such a demonstration unit on an interstate river system of some magnitude, involving several States and the Federal government, would be best suited for a demonstration of the possibilities of (a) better coördinated water-pollution control legislation in the several states, and between the States and the Federal government, (b) more adequate administration procedure by State agencies, (c) the development of the legal and administrative procedures for regional or metropolitan pollution-abatement authorities, (d) the coördi-

nation of municipal sewage-disposal projects with statewide or interstate projects, (e) clearing up unsolved problems of treating industrial waste, (f) the extension of coöperation with industry, and (g) the stimulation of public demand for adequate control of water pollution. Such a unit would not only aid in the solution of many perplexing problems of water-pollution control, but also would serve as a training field for the development of personnel, scientific and administrative, which would be competently trained for duty with other States or for absorption into an organization for a national program."

The opportunities for accelerating the installation of sewage and industrial waste treatment plants by the Federal grants-in-aid method were emphasized by the Special Committee. Although there is, of course, considerable opposition to the extension of Federal grants-in-aid, the history of sewage treatment installation in the last four years, in contrast with that of the previous 50 years, makes it apparent that such financial stimulation from a central agency, with proper safeguards, will do more probably to increase the number of necessary installations than any single measure so far discussed. Prior to 1933 there were several thousand sewage treatment plants in the United States, but since 1933 between 25 and 30 percent additional plants have been installed. In other words, in less than three years, with the assistance of Federal grants-in-aid, the rate of installation has been multiplied ten fold. In this field as in almost every other, we must weigh practical experiences and advantages against certain philosophical prejudices in order to decide on our future approach.

Balanced river regulation

Recent dramatic emphasis on the droughts and floods has concentrated attention once more on the all embracing problem of river regulation. As is always the case, also, the first effort of the layman is to correct the immediate difficulty, as it occurs, without reference to the general problem. When floods occur and damages are great, the public rushes to Congress for flood protection works. Their character and adaptability to the remaining program of stream regulation are lost sight of in the desire for immediate correction of serious difficulties.

In view of this tendency to ignore the necessities of balanced development of any drainage basin, the Water Resources Committee has considered the relation of various proposed investigations concerning floods and flood control and recommended the issuance of an executive order or memorandum designating the National Resources

Committee as a clearing house for information on flood studies. On May 14, 1936, the Acting Director of the Bureau of the Budget, by direction of the President, ordered all the Federal agencies to pursue this program of central clearance through the Resources Committee.

It suggested furthermore the allocation of additional funds to the National Resources Committee for proposed flood investigations, utilizing appropriate bureaus of the Federal or state government for the purpose.

In this latter connection, it felt that data on past flood stages and discharges, not already incorporated in recent studies, should be analyzed and compiled by the U. S. Geological Survey. It proposed furthermore that the less precise data concerning past flood heights and flows as recorded in private, newspaper and unpublished Government files, should be explored, compiled, reviewed, appraised and published.

A special inventory and study of cloudburst floods was proposed. These floods are of restricted extent, cause heavy damages within relatively small areas as at Pueblo and Cheyenne and can rarely be forecast by analysis of past storm records. By investigating the character of these recorded cloudburst floods, it might be possible to determine those parts of the United States which someday might be similarly affected.

Inasmuch as a number of Federal agencies were now collecting data concerning the 1936 floods the proposal has been made that these reports should be analyzed and summarized, with the pertinent material in lay terms to be issued in a single report for the education and use of official and lay boards throughout the United States.

The highly important problem of estimating whether or not the benefits from a given flood control project warrant the cost thereof was proposed as the topic for a special and detailed study by competent legal and engineering experts. The economics of flood control needs clarification through intensive investigation of conditions and techniques in consolidated areas in the United States. This proposal for the study of the economics of flood control is not of course new, but has been proposed vigorously and with intelligent basis particularly by the Committee on Flood Protection Data of the American Society of Civil Engineers.

Problems of the arid and semi-arid West

Special problems in the water works field have also been under study and reports thereon should materialize from time to time.

Detailed attention is being given to the water problems of the arid and semi-arid western states of California, Colorado, Idaho, Montana, Nebraska, Nevada, North Dakota, Oregon, South Dakota, Texas and Washington. A mass of information has already been accumulated through the coöperation of state officials in these areas dealing with the potential requirements of water resources for the future for purposes of navigation, power, irrigation, flood control, sewage disposal and municipal water supply. An inventory of available resources in this area is also in preparation. The balancing of potential requirements against available resources has already indicated in at least some of these States that critical problems will arise in the immediate future. How these difficulties are to be reconciled with the entire social-economic life of the communities is one of the objectives of the Water Resources Committee study in this restricted group of states.

From the preliminary reports submitted by the western state engineers and planning boards it is clear that the type of water utilization is specifically related to geographical and topographical features (as latitude, mountain ranges, coasts, and large rivers) in their effect upon wind currents and on the extent and distribution of rain and snow fall.

The location of State lines, irrespective of geographical boundaries, aggravates the problem by introducing legal difficulties and State jealousies. In general, the water utilization in relation to man's welfare has followed the sequence given below:

(a) For subsistence—in isolated groups and during primary development.
    1. Domestic use.
    2. Irrigation from streams.
    3. Irrigation from or by reason of storage.
(b) For subsistence—in towns, industrial units, and cities.
    1. Water supply from streams and wells.
    2. Water supply from or by reason of storage.
(c) For protection.
    1. Flood control by local measures (levees and temporary works).
    2. Flood control by storage facilities, many times far afield.
(d) For expansion.
    1. Development for navigation and power, first by local measures, and later in connection with far-reaching plans.
(e) For utility, comfort and pleasure.
    1. For power and recreational purposes.

In localities where the dependence for subsistence relies upon industries such as lumbering and mining, or where cities have arisen,

as transportation centers, the sequence is generally as indicated above, with the elimination of subdivision (a).

Problems not previously mentioned include pollution of streams from sewage and industrial wastes, prevention of saline infiltration near the mouths of certain coastal streams, the drainage of lands water-logged by irrigation or overflow from streams, and the difficulties encountered from silt carried by many western streams. These may fall in any of the above subdivisions.

In California more than 90 percent of the total water used is for irrigation. This state has recognized the necessity for utilizing its water to the maximum extent and the basic data have been determined in detail for the more important basins, to proceed with long-time planning. The most urgent problem at present is, perhaps, the supplementing of water supply for domestic and irrigation purposes, particularly in areas where the supply is secured from wells.

Colorado's particular problem appears to be the Transbasin diversion of water from the western slope of the Rockies to the eastern slope. Storage of flood waters is required in many cases to replace the amount diverted.

The domestic use of water in Idaho is apparently the most important, followed by the utilization of water for irrigation and hydroelectric development, then for recreational purposes, and last for industrial and mining use. The State of Idaho is suffering losses each year not because water is lacking, but because provisions have not been made for supplementary water for tracts already under irrigation through actual construction of conservation works. The crop less through lack of this provision in the year 1934 was stated to be upward of $40,000,000, independent of stock and other losses.

The immediate need for water in Montana and Nebraska is to supplement present inadequate supply on lands partly irrigated and to provide resettlement areas for farmers now residing on submarginal lands. Future need will require conservation of all available water supply.

Due to the nature of much of the drainage in Nevada where streams end in closed basins, enormous underground reservoirs are formed. There is, therefore, urgent need for an investigation of underground water resources and soil analyses to form the basis for development in this state.

The annual precipitation in some parts of North Dakota and South Dakota is generally sufficient for the raising of crops. In

others, however, important deficiencies recur. Domestic water supply for cities and continuous and ample flow of water in streams for sewage dilution present problems now being studied.

Texas presents a positive example of the relationship of rainfall to development. By reference to a map of the state, the change from the semi-arid region of west Texas to the eastern section of heavier rainfall is readily traced by the increase in the number of towns. Water is the chief asset of the semi-arid section of Texas, comprising two-thirds of the state. Without an irrigation supply, this section has comparatively small value.

A good example substantiating the conclusions presented above exists in the states of Washington and Oregon. Here the Cascade Range forms a definite line between the humid coastal regions and the arid or semi-arid interior. The annual rainfall on the western side varies from 45 to more than 100 inches, dependent upon elevation and distance from the coast and as it is well distributed, subsistence usually does not depend upon irrigation. The problems of utilization therefore relate to (1) water supply for towns, industrial units and cities, (2) the protection that is necessary from floods, (3) the continued development of the region through navigation and power, and (4) the promotion of recreational features. On the eastern side of the Cascades, precipitation ranges generally from 8 to 20 inches or less and irrigation for subsistence is a dominating factor. Here, and in practically all of the arid and semi-arid regions, development may generally follow the sequence already mentioned.

Water works statistics

An effort is likewise underway on the part of the Committee to simplify the collection of water works statistics throughout the United States. For some years in the past, data on various aspects of water use have been collected by a variety of official and unofficial national agencies. Duplication of material and of use, irritation of local groups and conflict in purpose, all indicate that some effort at coördination would be helpful. In order to accomplish this purpose, the Water Resources Committee has invited the American Water Works Association, the American Society of Civil Engineers, the New England Water Works Association and other allied official and unofficial groups to meet in Washington to agree on a standard statistical collection sheet which the National Resources Committee might circularize for the collection of necessary pertinent material.

When such collection has been made the material will be made available to any national agency of recognized standing which might desire to issue it for its own purpose and under its own imprint.

It should be made clear that the Resources Committee is not proposing to collect and distribute the material under its own auspices. Its primary desire is to avoid duplication in the collection of the material by whatever technique may be considered practicable.

Standard practice

Another enterprise in which the Water Resources Committee has recently been requested to act is concerned with the reconciliation of the preparation of manuals by the various Federal agencies on the design and construction of small dams. At the request of several Federal agencies the Committee has undertaken the task of reviewing and coördinating a number of manuals on this subject which have been in use by various Federal agencies over a number of years. The principles and facts of design in these manuals differ to a considerable extent and a coördination and reconciliation appear necessary.

The agencies recognize that the use of a variety of standards for the same purpose by individual arms of the same central government is beginning to cause confusion and difficulty. The Water Resources Committee at the request of these agencies will strive to reconcile these differences.

Most of the above discussion has been restricted to the operations of the Committee on general problems confronting the country as a whole. In its activities, however, it has undertaken specific studies where conflicts of interest or purpose have become so great that requests for external review by the National Resources Committee have appeared. Some of these instances are briefly presented below, as types of problems with which the country will be continually confronted until some mechanism may be developed in the next few decades to prevent their occurrence.

Upper Rio Grande River

Perhaps the most dramatic of these examples for the necessity of coördination is in the problems of the Upper Rio Grande basin above El Paso. In view of the fact that Federal appropriations have been made for a number of years in this particular drainage basin, the National Resources Committee in the fall of 1935 was requested to consider the various projects and problems relating to the use and

control of waters in that portion of the Rio Grande basin above El Paso.

To accomplish this review the Water Resources Committee appointed a Board of Review consisting of Messrs. H. J. S. Devries, W. W. McLaughlin and Harlan H. Barrows. So critical a situation was found by this Board of Review that immediate action was requested by the Walter Resources Committee for remedy of the situation. The Board disclosed the following facts:

1. The water resources of the upper Rio Grande basin are already fully appropriated.
2. The social security of many citizens whose living depends on water use encouraged by Federal investments is imperiled.
3. The security of financial investments made by various Federal agencies in this region is imperiled by any further appropriation of these waters.
4. A Federally authorized compact which expires in 1937 exists between the three states controlling these waters. Projects now seeking Federal allotment violate the agreement under this compact.
5. Progress toward equitable and permanent agreements under the existing compact may be achieved by immediate Federal aid and stimulation.

As a result of the recommendations of the Water Resources Committee, the President on September 23, 1935, instructed appropriate Federal agencies concerned with approval of allotments for water use in this drainage basin not to approve any application for a project involving the use of Rio Grande waters, without securing from the National Resources Committee a prompt opinion on it from all relevant points of view.

As a result of the further recommendation of the Committee that provision of coöperative funds and personnel be made by or through the National Resources Committee, a program is now in operation in coöperation with the existing interstate Compact Commission to prepare an inventory of existing water uses, water rights and water supply within the area. The study is intended to disclose the quantitative possibilities of increasing the supply through trans-mountain diversion and the like. Out of the study should come the factual foundation upon which equitable interstate agreement on water use may be brought to fruition within the lifetime of the present interstate compact agreement.

For the purpose of this study, several hundred thousand dollars have been made available from Federal and local sources to be ex-

pended under the general direction of Profs. Frank Adams and H. H. Barrows and through the various Federal and state agencies equipped and concerned with pertinent aspects thereof.

Mr. Harlow C. Stafford is in local charge of the program and it is his task to collect and coördinate the information necessary for the purposes proposed by the Water Resources Committee. At the time of his appointment Mr. Stafford was Water Commissioner for the Sacramento and San Joaquin Valleys of California.

Red River of the North

In the Red River of the North the Committee has under operation a similar study requested by the State Planning Boards of Minnesota, North Dakota and South Dakota. These agencies have established a joint committee on a permanent water plan for the Red River basin. The Chairman of that Committee is Mr. W. W. Horner of St. Louis, Mo., designated and employed by the National Resources Committee for this particular purpose. The joint committee has furthermore on its membership Prof. H. H. Barrows of the University of Chicago, a member of the Water Resources Committee. The other members of the Committee represent the various State Planning Boards concerned with the problems of flood control, water supply and stream pollution.

Under Mr. Horner's direction, studies are now under way for the development of data relating to the consumptive use of water, on the accumulation of water resources data with particular reference to quality and quantity, on the analysis of these data and the development of a long term plan for the Red River of the North. Great progress has been made in this undertaking through the complete coöperation of the various planning boards and of the other state and Federal agencies. The enterprise indicates how comprehensive a study can be undertaken under effective leadership by existing state and Federal agencies rather than by the creation of new structural machinery. The report on the Red River of the North should be available within a few months.

Kansas City flood protection

A similar study of the entire flood protection program at Kansas City has been under way for several years under the direction of Frederick H. Fowler. This study, is being made in coöperation with the U. S. Army Engineer Corps and with State and local participation.

The Water Resources Committee has contributed from time to time to the operation of this study and the local groups have matched these funds for the purpose of developing an adequate engineering and financial solution to this difficult problem. In order to accomplish this purpose to the best advantage, funds were made available during 1935 for the construction of models to develop technical answers to some of the highly complicated hydraulic problems. In this instance, as in those already discussed, the effort of the Committee is to enlist not only the financial but the technical participation of all interested Federal and local agencies. The report on this enterprise should be made available by the end of 1936.

TENTATIVE FUTURE PROGRAM

It should be clear from the brief description of the forms of activity which the Committee now has under way, that the major effort of the Committee should be permanently restricted to the tasks of planning, coördinating and stimulating the operations of central and local official and unofficial agencies. Much of the probable value of a National Water Resources Committee may easily be lost or diverted if the Committee embarks upon operating administrative functions, which should be restricted properly to existing or new administrative agencies. The energies of the Water Resources Committee should not be diverted to details of administration and the membership of the Committee is completely in accord with the desire to restrict its operations to those functions noted above.

A considerable extension in the collection of basic information regarding water resources is necessary for the most fruitful development of our water resources. The Committee intends to stress this necessity regularly and continuously. When this deficiency in basic data is being permanently and satisfactorily met, other opportunities for intelligent water use and control programs will no doubt appear.

The development of drainage basin economies

Problems in the use and control of water resources of the nation are not new. Their importance, however, becomes clearer and clearer as competition for and conflict in their uses become more frequent and intense. The geographical distribution of such conflicts varies from time to time and it is only in recent years that the controversial aspects of western water resources have penetrated into the east. Increases in population, more varied uses for water supply, competi-

tion between municipalities and industries for relatively limited quantities of water all tend to focus attention of the public upon a problem as old as civilization itself.

Periods of drought succeeded by periods of flood flow in the past six years have emphasized once more, but with greater dramatic effect, the fact that water is a menace to life and property as well as a necessity for the continuance of our existence.

The study of water resources is likewise not a novel enterprise, for many millions of dollars and many years have been spent in their detailed study. In few instances, however, have our agencies been so constituted as to make it possible to review the national water problem as a whole and in particular relation to the economic and social situation of the country, as exemplified in land use, industrial development, population trends and the requirements of health and recreation. In this field as in all others, the detailed immediate problem, specific in nature and local in implication, has naturally held the attention in the past. This is by no means surprising in a country of rapid growth and, until recently, except in limited geographical areas, undisturbed by the specter of resources decreasing in proportion to need. The pressure of immediate solution of specific problems of water use and control so often may preclude the balancing of all uses or even of their prior review.

In recent years, however, even in the eastern part of the United States, nature has reminded us that conservation of water resources and balanced development for their use and control cannot be ignored in successions of droughts and floods. With these lessons in mind, the National Resources Committee, through its Committee on Water Resources, is undertaking a national study of water use and control in the major drainage basins of the United States. The Committee hopes to obtain a reasonably clear picture of the long range pattern for each important drainage basin and at least a preliminary list of projects which may be properly constructed in keeping with that pattern. This preliminary plan or reconnaissance it is hoped will be submitted to the President of the United States on December 1, 1936. This can only be accomplished through the complete cooperation of state and regional planning boards, of interested Federal, state and local agencies and of private industry.

By this effort the Committee is attempting to provide a sound and nationwide outline for securing the greatest beneficial use of the water resources of each major drainage basin in the United States.

Obviously with the limited time and financial resources available for the study only a skeleton plan, largely of preliminary character, is feasible. Such a bird's-eye view, however, of the national problem and of the available data shedding light thereon should be the beginning of recurring and continuing adjustments in each major basin.

By this study the Committee should also be able to furnish various Federal, state and local agencies a clear statement of the dominant physical and economic considerations affecting the use and control of water resources in each basin, even though such a reasonably integrated pattern of development can be prepared only in broad outline. Out of this study a series of specific construction projects should also appear which might properly be executed as time goes on, in accordance with the integrated plan of ultimate development.

To those of you familiar with various parts of the United States, it should be clear that uneven programs of development will necessarily result from this study. Some areas of the country have been intensively studied for years while others have had little or no detailed review by either state or Federal agencies.

In the latter areas, the elements of an investigative program for further study and revision of the general program which may be outlined during 1936 are to be presented.

The three major objectives, therefore, of the Committee in this proposed study of drainage basin water resources are:

(1) To indicate the outstanding problems of water use and control in the different parts of the country.

(2) To outline in broad terms a reasonable and integrated pattern of development, and

(3) To present specific construction and study projects which, in in the light of available information, are consistent with the broad plan.

Questions of administration and financing of programs and projects developed in the study will not be reported upon in any detail, since they offer problems of national policy which can be determined only after long discussion in the public forum.

Specific recommendations will vary greatly in detail from one basin to another. In one basin further surveys and investigations may be recommended before any construction work is proposed. In another, it is probable that a number of projects ready for construction or requiring a short period of detailed design, may be recommended. The Committee, of course, will not attempt to prepare detailed plans

and specifications for construction projects, although it will enumerate projects for which plans and specifications are already available.

In order to provide working arrangements with state planning and other boards, and to secure the continuous views and criticisms by state and Federal authorities, the Committee has assigned 15 water consultants to work with the state and regional boards. These consultants will be responsible for the conduct of the field work necessary for the preparation of the water plans. They have been selected according to major areas and convenience of operation. They will be responsible for the review of existing information and reports, for the crystallization of long range plans and for the preparation of a final document embodying the answers to the three major objectives already pointed out above.

Organization

The field and office operations leading to the preparation of the report proposed are under the direction of Frederick H. Fowler of San Francisco, California, a consulting engineer of wide experience in water resources problems. He is a past director of the American Society of Civil Engineers, a member of its Committee on Dams and on Flood Protection Data, a former member of the Federal Emergency Public Works Administration Technical Board of Review and a consultant on flood control problems in the Kansas City and Los Angeles regions.

The assistant director is Merton L. Emerson of Boston, Massachusetts, a consulting engineer and a former member of the Public Works Administration Technical Board of Review.

The Water Resources Committee will outline and supervise the study through the special organization established under Mr. Fowler's general direction. The drainage basin districts so far organized and the water consultants assigned to them are as follows. All of the studies are now under way and the detail of accomplishment must wait upon the receipt of the preliminary reports of these consultants.

Drainage Basin District No. 1:
Prof. H. K. Barrows, Boston, Mass.
Drainage basins in Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and New York, including the Housatonic as the westernmost basin.
Drainage Basin District 2:
Nathan B. Jacobs, Pittsburgh, Pa.

North Atlantic drainage basins in Connecticut, New York, Pennsylvania, New Jersey and Delaware west of the Housatonic and including the Susquehanna as the most westerly drainage basin.

Drainage Basin District 3:

William McKinney Piatt, Durham, N. C.

Chesapeake Bay and South Atlantic drainage in Maryland, Delaware, West Virginia, Virginia, North Carolina and South Carolina, south of the Susquehanna basin, including Port Royal Sound drainage as the most southerly basin.

Drainage Basin District 4:

Dean Blake Van Leer, Gainesville, Florida.

South Atlantic and Eastern Gulf drainage in South Carolina, Georgia, Florida, Alabama and Mississippi from the Savannah basin on the northeast to Mobile Basin on the southwest, both inclusive.

Drainage Basin District 5:

Frederick H. Weed, Cincinnati, Ohio.

Ohio River drainage in New York, Pennsylvania, Maryland, West Virginia, Virginia, Kentucky, Tennessee, Ohio, Indiana and Illinois.

Drainage Basin District 6(a):

Royce J. Tipton, Denver, Colorado.

Southwest Gulf of Mexico drainage, south and west of Vermilion River, Louisiana and including drainage in the United States entering the Rio Grande south of Fort Quitman, Texas.

Drainage Basin District 6(b):

Gerard H. Matthes, Mississippi River Commission, Vicksburg, Miss. (By detail from Corps of Engineers, Mississippi River Commission.)

The Alluvial Mississippi Basin and Gulf of Mexico drainage, in the States of Mississippi, Tennessee, Kentucky, Missouri, Arkansas and Louisiana, from Pascagoula River on the East to Vermilion on the West, both inclusive, and northerly to the mouth of the Missouri; excluding the main drainage basins of the Ohio and Missouri and the free-flowing portions of the rivers south of the Missouri tributary to the Mississippi on the west, but including such problems and projects on the lower courses of said tributaries as are related to Mississippi River backwater control.

Drainage Basin District 6(c) and 6(d):

Wesley W. Horner, St. Louis, Mo.

Western Mississippi River drainage in Louisiana, Texas, New Mexico, Colorado, Oklahoma, Kansas, and Missouri, from and including the Red River basin on the south up to the southerly edge of the Missouri River basin, but excluding the portions of said basins which are subject to flooding from the Mississippi River.

Drainage Basin District 7(a):

Wesley W. Horner, St. Louis, Mo.

Mississippi River Basin Drainage North of the Ohio and Missouri Basins, in Missouri, Iowa, Minnesota, Wisconsin, Indiana and Illinois.

Drainage Basin District 7(b):
LeRoy K. Sherman, Chicago, Illinois.
Great Lakes and St. Lawrence River Drainage in Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania, New York and Vermont.
Drainage Basin District 8:
Prof. S. T. Harding, Berkeley, California.
The Northerly portion of the Missouri River basin, to and including the basin of the Platte River on the west side, and to and including the basin of Mosquito Creek on the east side, in Iowa, Minnesota, South Dakota, North Dakota, Montana, Wyoming, Colorado and Nebraska.
Drainage Basin District 9:
Frederick H. Fowler, Washington, D. C.
The portion of the Missouri River Basin south of the basin of the Platte River on the west side and south of the basin of Mosquito Creek on the east side, in Missouri, Iowa, Nebraska, Colorado and Kansas.
Drainage Basin District 10(a):
J. C. Stevens, Portland, Oregon.
The Colorado River basin in Arizona, New Mexico, Colorado, Wyoming, Utah, Nevada and California, together with the Imperial Valley and Salton Sea drainage basin in southern California.
Drainage Basin District 10(b):
Walter L. Huber, San Francisco, California.
The Great Basin drainage in California, Nevada, Utah, Wyoming, Idaho, and Oregon.
Drainage Basin District 10(c):
Ralph I. Meeker, Denver, Colorado.
Southwest Pacific drainage in California and Oregon, to and including Smith River basin on the north.
Drainage Basin District 11:
Prof. Samuel B. Morris, Leland Stanford University, Palo Alto, Calif.
Northwest Pacific drainage in Oregon, Nevada, Utah, Idaho, Wyoming, Montana, and Washington, from and excluding Smith River basin on the South.

To facilitate the work of these consultants and to maintain a continuous and completely coördinated contact with state and regional planning boards with Federal agencies and with other coöperating agencies, regional coördinators have also been appointed by the National Resources Committee. These individuals will travel throughout the country for the purpose of assisting the water consultants and keeping them currently informed of various phases of the study so that uniformity of approach and of ultimate reporting will be assured. To accomplish this purpose the country has been

divided into two major areas, the western area, covering Districts 6(a), 6(c), 6(d), 8, 9, 10(a), 10(c), and 11. The eastern coördinator, Howard Critchlow of Trenton, New Jersey, will cover Districts 1, 2, 3, 4, 5, 6(b), 7(a), and 7(b). These areas are listed in table 3.

The compilation of existing lists of rated water projects under new and improved rating methods will be under the supervision of an office coördinator, Brent S. Drane, who has had considerable experience in this field with both the Water Planning Committee of the National Resources Board and the Water Resources Section of the

TABLE 3

Tentative subdivision of the United States into areas for water resources study

1.	New England
2.	Middle Atlantic
3.	Southeast Coast
4.	Southeast Gulf
5.	Ohio Basin
6a.	Southwest Gulf
6b.	Lower Mississippi Basin
6c.	Red River of the South and Arkansas Basin
7a.	Upper Mississippi Basin
7b.	Great Lakes and St. Lawrence
8.	Upper Missouri Basin
9.	Lower Missouri Basin
10a.	Colorado Basin
10b.	The Great Basin
10c.	California
11.	Pacific Northwest

Note: The Red River of the North and the Upper Rio Grande Basin are not segregated because work is already under way in those basins.

The Tennessee Valley is omitted.

National Resources Committee. It will be his function to amplify existing lists of water projects throughout the United States by the addition of all new water projects planned by Federal, state and regional agencies and such other projects as may be developed by the field forces and ultimately approved by the Director and the Committee. He is to act further as liason officer with all Federal agencies concerned with the economic problems affecting or affected by the plans of the drainage basins. The coöperation of other committees and agencies of the National Resources Committee on land, minerals, power and industrial resources is to be secured through his efforts.

From time to time special consulting service will be available to both field and office organizations in the solution of complex technical problems involved in comprehensive basin planning. Such men will be on call to render service when requested by the Director or Assistant Director.

It should be emphasized that, when these preliminary inventories and crystallizations have been completed, no mere compilation of projects now on file in various state and Federal agencies should be the result. For the first time in the history of this country the various Federal, state and local interests in a drainage basin are to be brought together in the field for the development of the broad program. Aside from the important end result of developing a preliminary long range plan, the study should go far toward initiating coöperative planning activities in the field of water resources which it is hoped will continue long after this first national study has been completed. Progressive modification, refinement and adjustment of program should be the continuing ultimate aim of this first effort. The broad picture here proposed for the water resources of the United States will be the frame-work within which more detailed study and evolution should take place in the future.

DISCUSSION

EDWARD HYATT (*State Engineer, Sacramento, Calif.*): Chairman Wolman's illuminating review of the work of the little known National Water Resources Committee is of great interest to this writer, not only for its report on the material accomplishments to date, but also for its exposition of the purposes and policies under which the committee functions, which seem to point the way for the sane constructive planning of the coördinated development of the national water resources in the future.

The subject is tremendous. Billions have been spent on water works and control, and additional billions will be spent in the future. The important uses of water are many and are increasing both in character and amount, as are allied problems of control and of quality. Serious conflict between types of use and between states exists, which is bound to grow steadily worse. The appearance of a National Board to lead the way in solving these great problems is indeed an item of importance and encouragement.

Mr. Wolman points out that the Committee limits its activities to questions affecting the national government, except as its assistance

is requested by states or other agencies. He notes the existence of some 35 Federal agencies dealing with water, and the correlation of their activities by the Committee, which is being accomplished with a surprising degree of success. Here is one field in which there is an obvious need of such a coördinating body, and which alone would justify the Committee.

However, there are far more important tasks ahead of it, many of which are under attack. The encouragement of the collection and standardization of basic hydrologic data, for one. Intelligent planning, even for one use, is difficult without accurate data, which is sadly lacking in quantity, quality, and standardization. For another, interstate water problems and the furnishing of competent, impartial assistance in the adjudication of existing major controversies, such as on the Ohio River in the east or the Rio Grande in the west.

But the great possibility that lies before this Committee, its greatest hope, is in the planning in advance of the national water developments of the future, to the end that past mistakes may be avoided and that the greatest use, at the least cost, may be made of this country's water resources.

The Committee has courageously made a start on this problem in its drainage basin study. Its time is short, its funds are small, it is handicapped in many ways, but it will be a start, and do not forget that "mighty oaks from tiny acorns grow."

The Committee is studiously avoiding interposing or interfering in local or intrastate water questions, as is proper, but hopes to induce and assist state planning agencies to follow its example and extend sound comprehensive principles to state and local water development planning. The Committee's field is purely national, but its assistance particularly in the formative period is available to state boards, and it is to be hoped they will take advantage of it.

A technical board, rigorously non-political, the Committee's accomplishments in less than a year, as related by Mr. Wolman, have been constructive and useful, not only in Federal departments, but to many states.

The need for accurate data and careful planning for future water works is imperative and therefore the need for state and national water planning. Political administrations and personnel of planning boards will change, but studied water development planning by experienced and impartial men is not only a sound idea, but a neces-

sary one, if the best use of this limited natural resource is to be attained.

The Water Resources Committee is entering a most important but uncharted field, and is to be congratulated upon its initial progress. Its work should continue through the years and decades and should expand under state and local auspices. Is it too much to hope that from this auspicious start will come, in the future, comprehensive, economical and non-political control and utilization of our water?

THORNDIKE SAVILLE (*New York University, New York, N. Y.*): This paper is so admirable and comprehensive that the writer can contribute little in the way of discussion, other than to point out certain implications of the current and possible future activities of the National Water Resources Committee. In a paper presented before this Association in 1935[1] the writer indicated in some detail the present status of basic hydrological data, and the expanded program for the collection, analysis, and publication of such data if the water resources of the country were to be developed and conserved in a manner best adapted to promote their economic, orderly, and sound utilization in the interest of public health and public welfare. Most water engineers are agreed that such a program is desirable and that its execution is properly a federal function. Mr. Wolman has indicated that after a careful study the Water Resources Committee has prepared definite proposals to effectuate this. It is to be hoped that the forthcoming report will be carefully scrutinized by water engineers and that they will initiate appropriate steps to see that its proposals are carried out.

The writer, having been himself for many years in charge of a state agency dealing with water resources, is familiar with bureaucratic points of view. He is firmly convinced that in federal and state governments numerous agencies must deal with specific aspects of water conservation, but that coördination is essential in the interest of avoidance of duplication, prevention of conflict in objectives, and conformity to a well considered plan for water resources use and control. Several procedures commend themselves to him to bring order out of a situation constantly becoming more chaotic. These are:

1. The numerous federal agencies dealing with water problems

[1] "Deficiencies in Present Water Resources Information," by Thorndike Saville. Journal, American Water Works Association, August, 1935.

should have a medium for coördinating their plans and activities in harmony with a developing national water policy.

2. A national water policy should be evolved, enunciating certain basic procedures, and susceptible to change as national and local conditions alter.

3. The relationship of state to federal, and of interstate interest and concern with water problems should have a common meeting place where conflicts of opinion and interest may be subject to informed group discussion and decision.

4. Means should be provided whereby a qualified but relatively disinterested non-political and non-departmental agency may initiate and guide coöperative investigations to determine the basic factors essential for reasonably harmonious solutions of numerous intricate and vexing water resources problems.

5. The official government agencies, whether state or federal, should be furnished with a review of their procedures from time to time by competent non-government experts.

Items 4 and 5 serve a double purpose: they bring the organized viewpoint of the user of hydrologic data to the collecting, policy making and administrative branches of government, and help to maintain the field of the private practitioner. This last is regarded by the writer as a particularly desirable objective in times like the present when government agencies are more and more monopolizing all of the elements concerned with water policy and water conservation. The constant review and opinion of non-government experts is regarded as necessary to promote vigorous and progressive action by government agencies and to stimulate and maintain the best traditions of a democratic people.

A perusal of Mr. Wolman's paper should indicate that all of these objectives have been constantly in the minds of those guiding the development of the present Water Resources Committee.

C. G. GILLESPIE (*State Sanitary Engineer, Berkeley, Calif.*): It is unbecoming that I should express as assigned, the point of view of California on this highly important activity of the Federal Government. I may speak some of the views of some of the engineers and of others in this State, but obviously not of all. Summed up, I believe it is safe to say no one questions the wisdom of wise planning and development of water resources that the greatest good may come to the greatest number. California can surely attest to its belief in

this creed by its own farsighted planning from its infancy as a State, particularly in the use of its water resources.

In fact, so far has this program of development of water resources advanced here that it is doubtful that this State can profit particularly from the pending Federal activities, as described so ably by Mr. Wolman. The principal concern many may have is what turn these Federal activities may take—whether they will remain on the present salutary basis wherein the various committees simply operate in effect as clearing houses and as "Boards of Inquiry" to which local authorities can or shall bring their plans to be harmonized and polished, or whether out of impatience with the occasional imperfections and slowness in that program, or spurred on by bureaucratic instincts, the whole job will be moved to Washington, with collapse of local initiative and planning.

California is hemmed in by its own mountains and aside from the Truckee River which flows out of the State into Nevada, and the Colorado River along its borders, it has no interstate water problem. To Nevada, California has always been a good neighbor. With Arizona the division of the Colorado River has been worked out through Congress and the Federal Courts and that problem is behind us.

Not only does California feel keenly its independence, resourcefulness and self-reliance as a State, but so do the smallest subdivisions of government. It is one of the heritages left by the intrepid pioneers of the Gold Rush days. In consequence, government is very much decentralized.

In these matters of water planning, the electorate on two occasions in recent memory defeated propositions which would have set up a State agency with powers such as the Federal activities might easily develop into, for planning and developing the water resources of the State. This may show how jealous are local communities of their prerogatives.

Few states can point to more or larger or better built water supply developments than here. For example, the water supply of San Francisco from early days under Hermann Schussler to the present Hetch Hetchy project; the Owens River project engineered by Wm. Mulholland of this City of Los Angeles; the Mokelumne River project of the East Bay Cities; the Colorado River project for Southern California; the All-American Canal; the Central Valleys project, planned by the State Engineer, although it may be built by the

Reclamation Service; the huge hydro-electric developments in the Sierras and several well planned and extensive irrigation projects. Only the All-American Canal, the Central Valleys project and the Colorado River project have been aided financially by the Federal Government and this by reason of the depression years. All the others are the entire work of the several localities. In this State it has been safe to leave these affairs in local hands. The Colorado River project and the Central Valleys project will do much to relieve the drain on underground supplies to which Mr. Wolman refers as our California problem.

From the fact that California was a prospering State, with good markets, these large projects were not so premature but that their revenues justified the investments and made financing through private channels comparatively simple. This may not be true in some of the other States and they may need a certain amount of Federal support. However, it may imply that some of their projects may not be profitable. If so, then to the extent that projects fail to pay, the burden must of course be shifted onto other States, including ours. I suspect it will be difficult for the Federal Government to resist the pressure for unwise and premature projects, just as was the case with some of the Reclamation Projects years ago.

In an arid state like California where there is not water enough for all, there have been scores of bitter conflicts over water and water rights. However, like the frog that fell in the pail of milk and kicked until he made a little island of butter from which he hopped on his way, the parties concerned have, through the years, settled most of their difficulties by litigation or by mutual agreement, involving also rationing of water and its more economical use and a materially improved duty of water. Procedures and decisions which have evolved have made settlement of such cases easier through the years. We might have avoided some of these conflicts had there been a system of voluntary or compulsory submission of projects to outside review in advance.

Commenting on the proposal that Federal subsidies be strengthened as a means of arousing local initiative, particularly in the anti-pollution phase of these Federal activities, I cannot quite imagine how only a part of the projects will be built by subsidy and the remainder at local expense. In the recent depression years we have had no sanitary projects except those built by some form of Government subsidy. All have held off, waiting for subsidy. If subsidies

are to be in the permanent plan, cities will continue to hold off doing anything until Federal money can be gotten. Therefore, unless the national purse is prepared to finance all sewage disposal involving streams and water resources, it would follow that the long time progress may be actually slower than that by local initiative. On the other hand, Federal advisory help to the States through capable stream pollution experts, would undoubtedly promote progress in cleaning up streams and beaches.

This matter of maintaining local enterprise and initiative seems to me to be the compelling consideration and the hardest problem in the scheme of safe Federal planning of whatever nature. Mistakes in physical and economical affairs are not irreparable but self-reliance of individuals, once destroyed, takes generations to revive.

SAMUEL B. MORRIS (*Stanford University, Calif.*): The paper by Mr. Wolman so fully presents the recent Federal activities in the conservation of water resources that there is little opportunity to add to the already complete picture he has so admirably drawn. Growing annual expenditures of an earlier range of 30 to 63 million dollars to 374 million dollars in 1935 and the existence of over 35 individual Federal agencies with little or no coördination demanded the creation of such an agency as the Water Resources Committee of the National Resources Committee.

The Water Resources Committee has ably met its responsibilities and opportunities. Composed primarily of the directing heads of the principal Federal agencies related to water resources, with the addition of four engineers representing private professional practice and eastern and western states, the Committee is excellently organized to combine first-hand knowledge of the country's water problems. At the same time it is in best position to bring about friendly, understanding coöperation among the separate bureaus that have so long operated independently of each other.

I understand that it is the announced purpose of the Water Resources Committee to coördinate the Federal and Federal-local activities in water planning and development in the collection of basic hydrological data, the resolution of conflicts of interest or purpose, the extension of basic information, the development of drainage basin economics and, as a natural result thereof, the promulgation of works priority lists which would fit into the gradually crystallizing pattern of drainage basin economy.

The committee has very wisely refrained from any desire to become a principal fact-finding or constructing agency. Rather it has decided to become a semi-judicial body, hearing the various conflicts of interest and attempting to coördinate and harmonize such conflicting interests and to aid and stimulate the regularly established Federal and local agencies in more effectively carrying on their established duties. It is only by such non-direct participation by the Water Resources Committee that it can fully retain its superior position as a coördinating, harmonizing, energizing, and policy-determining agency in developing and bringing into fruition a far-reaching national water policy in the development of the country's water resources.

It is also important that the Committee refrain from participation in and recommendations upon the ever-present problems of reorganization of existing Federal agencies, and must have nothing to do with policies of expansion, contraction, consolidation or abandonment of present Federal agencies related to water resources.

Studies have already shown that unnecessary waste and delay have occurred in unharmonized water storage and drainage projects carried on by separate Federal bureaus. Much progress is already being made by the simple expedient of bulletins circulated among Federal agencies stating the projects studied or contemplated by each agency.

Mr. Wolman has very properly laid stress upon the need for some staff organization to review, sift, and reconcile the work and purposes of the independent Federal agencies for the use of the President or of Congress.

Evidence that the activities of the Committee are already under way are reports of the several special advisory committees and subcommittees on Drainage Policy and Projects, Water Pollution, Standards and Specifications for Hydrologic Data. Special studies by the Committee in Balanced River Regulation, Collection of Water-Works Statistics, in which the American Water Works Association and other technical societies are assisting, correlating standard practice in construction of small dams, are receiving attention.

In addition to these important contributions to the general field, the National Resources Committee has been instrumental in securing immediate special studies on some of the more critical problems of particular stream systems. These include the Upper Rio Grande, where the safe yield of the river has already been appropriated; the Red River of the North, a sample coöperative drainage basin study; and Kansas City Flood Protection, a highly complicated flood-control problem.

And now the Committee has begun a most ambitious undertaking in its drainage basin studies, in which a nation-wide study of water use and control in the major drainage basins of the United States is being carried forward, with report to be completed this fall. The fact that only limited time and financial provision for the study are available will hamper the completeness of this report, but should not prevent procurement of a broad view of the national problem.

Recent occurrences of unprecedented drouth, now followed in many instances by devastating floods, have awakened the public to new interest in control and utilization of the country's water resources.

On a very large scale, the work of the Tennessee Valley Authority in the coördinated economic planning for the best utilization of the water resources, land, and industry of the important Tennessee River Valley will be watched with great interest.

The longest rainfall records of the Pacific Coast only go back 85 years, a very short period of history. In the past few years, in many areas of the country, new records of sustained drouth have occurred. Records of lake levels of closed basins and study of tree rings and fragmentary observations of early writers indicate more severe drouths have occurred in the more distant past. If such have occurred they are likely to occur again. The same may be said of records of excess rainfall and floods. There is great need, particularly in the semi-arid west, where developments are limited by available water-supply, for extended research into long-time departures from normal of rainfall and other climatic conditions. The Water Resources Committee might well bring about such study and research by one of the existing governmental agencies or by aid to other properly equipped research agency.

The increased participation of the Federal Government in bearing the cost of projects affecting water resources, many of which were previously looked upon as local problems, brings attention to the urgent need for development of a well-defined policy for the United States Government in relation to Federal participation and in the proper allocation of costs between the United States, state and local agencies benefiting thereby.

Perhaps the greatest opportunities and contributions of the Water Resources Committee will be in stressing the importance of continuous collection of more adequate hydrological data, including the completion of the topographic map of the United States, and in bringing to consciousness of the public and its elected representatives,

local and national, the necessity for coördinated planning for the best utilization of the water resources of each major drainage basin.

HARRY E. JORDAN (*Indianapolis Water Company, Indianapolis, Ind.*): Mr. Wolman's account of the activities of the Water Resources Committee is a high-minded and broad-gauged approach to a national problem.

Is he a Daniel come to judgment or a Daniel in the lion's den? His underlying theme is set out in these sentences:

"The axioms—that the most beneficial use of water resources of any valley should be related to the development of other physical resources; that development of any one phase of water resources should be considered in relation to all other phases; that physical factors are of importance in relation to cultural and economic conditions; and, that present as well as future aspects should play a part in any program;—must lead to the conclusion that competent administrative authority over water use and control is necessary for the determination of equities for the establishment of the most equitable allocation of uses and for putting into effect the results of such studies."

When he speaks in terms of "any valley," the broad implication extends to all the river valleys of these United States and contemplates the continued existence of a fact finding and correlating agency "restricted to the tasks of planning, coördinating and stimulating the operations of central and local official and unofficial agencies. Much of the probable value of a National Water Resources Committee may easily be lost or diverted if the Committee embarks upon operating administrative functions." . . .

Less gracefully put, this means that the "water rights" of no user are unlimited and a central agency exists which should continue to interpret these limitations in as disinterested a manner as the "environment" will permit.

Even a "Tory," when his water rights are damaged, will welcome such an agency, but a true "Liberal" is not so sure that the environment in which this central agency has to work has adsorbed much of its high-mindedness.

One may grant Mr. Wolman's interpolated remark, during the course of his address, that this committee, dealing with human as well as strict engineering problems, cannot work "in a vacuum." True. But one may properly fear that, from a vacuum, the committee may be drawn, more rapidly than its members would wish to admit, to the pestilential atmosphere of a political septic tank. Or

that it may find itself diverted by the fairy wand waving of the social worker, unaccustomed to, but now in possession of, vast funds for relief work.

What really underlies the creation of the Water Resources Committee? Can it be that the partial or complete underwriting of a large amount of local, state or regional water resource development by Federal agencies is forecast as a permanent policy?

Are we witnessing the establishment of, as a permanent function of the Federal government, an activity which three years ago most of those who advocated it, thought of only as an emergency procedure to relieve the depression? Or does it happen by some heavenly chance that the committee is really constituted as an agency for coördination of traditional and long term governmental departments?

As much as one might hope that the latter is true, one fears that the former represents the fact.

Why use the word "fear?" Simply because one apprehends that with the growth of the Federal debt structure and the increase of central control over many activities, the number of really competent and high-minded men to administer these activities is far too few.

Planning? Foresight? Rational allocation of water resources? There is no quarrel with the theory of any of them. But one can seriously doubt the existence of such a deep laid tradition of public service in the mind of the mass-American that will permit such groups effectively to promulgate their findings.

The only bit of silver lining in the cynic's clouded mind is afforded by an apparently increased willingness, in some quarters, to approach some water resource problems upon an interstate compact basis.

If by chance we can foresee central fact finding joined with state and regional agreement supported by a broadly diffused popular interest and support, we can almost vision the millenium.

(Presented before the Annual Convention of the American Water Works Association, Los Angeles, California, June 9, 1936.)

DIGEST OF REPORT OF N. E. W. W. A. COMMITTEE ON PIPE LINE FRICTION COEFFICIENTS AND EFFECT OF AGE THEREON

By Elson T. Killam

(*Consulting Engineer, New York, N. Y.*)

In November, 1933, a Committee of the New England Water Works Association was appointed to investigate and report upon the question of pipe-line friction coefficients.

A brief progress report was submitted in September, 1934, at the Boston Convention, and the data collected and compiled by the Committee were subsequently presented in a report comprising the September, 1935 issue of the Journal of the New England Water Works Association.

A summary of the scope of this report and the conclusions presented therein are reviewed in the following abstract:

The general conclusions drawn from the data submitted to the Committee are as follows:

1. *The average actual loss in capacity of tar-coated cast-iron pipe after 30 years of service, based on tests on a total of 473 pipe lines in 19 different systems, was 52 percent.*

   The loss predicted in the Williams-Hazen Tables for mains of similar age and diameter (average 20.5 in.) and for "average soft unfiltered river water" is 32.3 percent.

2. *Based upon the data available to the Committee, the Williams-Hazen age-coefficient relation was found to be applicable primarily to large-diameter mains carrying relatively inactive water.*

3. *For small-diameter mains carrying active water, the actual loss after 30 years may be twice the Williams-Hazen predicted loss.*

4. *Other factors being equal, the data show marked correlation between pH value of water carried, and rate of capacity loss. Average conditions reported indicating for supplies with a pH value of 6.5, twice the loss observed in supplies with a pH value of 8.0.*

SCOPE OF REPORT

The principal objective of the report was the presentation of heretofore unpublished data upon friction coefficients of tar-coated cast-iron pipe, with particular reference to the age-coefficient relation for this type of pipe, and the effect of water quality upon rate of capacity loss.

The report also contains sections dealing with various remedial measures for reducing and preventing loss of capacity, including discussions of coefficients of cement and bitumastic-enamel linings; methods of lining pipe in place; corrective treatment of the water carried; and pipe cleaning.

Certain other subjects not involved in the question of discharge coefficients of tar-coated cast-iron pipe, but falling within the general scope of the subject of "Pipe Line Friction Coefficients," have been presented in the form of appendices, in order that this additional information might be made readily available in a single report.

PRECISION OF DATA USED

The Committee endeavored to compile *mass data of reasonable precision*; obviously, the widely varying conditions found, and the many factors involved, could not be generalized upon any other basis. Accordingly, while the collection of data was in no way restricted to sources affording "laboratory" precision, the material presented included only such data as were considered to fall within the limits of reasonable precision set by the Committee.

This policy of precision applied particularly to the presentation of various "*trend curves*," which is the designation adopted for expressing the age-coefficient relation. The "*trend curves*" in which values of C were plotted against the age of the pipe in years, were presented only in cases for which numerous tests of reasonable accuracy were available.

In considering the trend curves it should be emphasized that the results represented *actual field tests* and accordingly included all incidental losses due to irregular line or grade, and due to fittings or special castings.

USE OF WILLIAMS-HAZEN COEFFICIENT "C"

The Williams-Hazen formula was used throughout the report for the determination of coefficient values, and all values of C refer to the Williams-Hazen coefficient in the formula appearing at top of p. 1295.

$$v = C\, r^{0.63}\, s^{0.54}\, 0.001^{-0.04}$$

v = Velocity in feet per second;
r = Hydraulic radius in feet;
s = Hydraulic slope in feet per foot;
C = The Williams-Hazen Coefficient.

In translating values of C to equivalent capacity loss, it is convenient to bear in mind that capacity is directly proportionate to the value of C. With slope and diameter fixed, a drop in the value of C from 130 to 65 consequently involves an equivalent capacity loss of 50 percent.

COEFFICIENTS OF TAR-COATED C. I. PIPE

Tar-coated cast-iron pipe has been more widely used in water works practice than any other type of pipe, and discussion of coefficient values with this type of pipe was accordingly selected for the first and principal subject of the report.

In considering the existing condition of old pipe, and attempting to determine the loss of capacity with age, selection of a value of C for *new pipe* becomes a fundamentally important assumption. The values of C for new tar-coated cast-iron pipe adopted in the report are as follows:

For supply and transmission mains 16 inches and larger in diameter ..... $C = 135$
For distribution mains less than 16 inches in diameter, with allowance for Ts, Valves, Bends, Corporation Cocks, or other specials involving friction loss ..... $C = 125$

Variations possibly approaching 10 percent higher or lower may be found, but the foregoing represent the average values from data available to the Committee.

The most widely used basis for estimating the probable loss of capacity of tar-coated cast-iron pipe with age (other than the convenient, though inadequate, assumption that C = 100), is the age-coefficient relation shown in the column headings of the Williams-Hazen tables.

These Williams-Hazen *predicted* age coefficient relations—or trends of C—accordingly form a convenient basis for comparison with *actual* trends computed from the data submitted to the Committee.

The data compiled on actual trends of the age-coefficient relation for tar-coated C. I. pipe includes tests on 473 independent pipe lines

in different cities. These data, results of which had not heretofore been published, were classified and presented in the form of trend curves.

These trend curves, as in the assumption of values of C for new pipe, were segregated into two major classifications, namely, for supply and transmission mains 16 inches and over in diameter, and for distribution mains less than 16 inches in diameter.

Further classification was made by grouping trend curves of similar type or source of supply; or according to general location or type of supply.

SUMMARY OF DATA ON ACTUAL CAPACITY LOSS IN TAR-COATED C. I. PIPE

The data on actual loss of capacity in Tar-Coated C. I. mains may be briefly summarized, as follows:

Supply lines in 9 cities showed a loss after 30 years of 37 percent as compared with a predicted Williams-Hazen loss of 30.8 percent.

Distribution mains in 10 cities showed an actual loss in 30 years of 64 percent as compared with a Williams-Hazen predicted loss of only 37 percent.

Average results of 473 tests in 19 individual systems, including sizes ranging generally from 6 to 48 inch in diameter, with a weighted average size (according to numbers of tests of each size) of 20.5 inches, showed an actual loss in 30 years of 51.5 percent, as compared with a predicted loss of 32.3 percent for pipe of the same diameter and age.

These data accordingly indicate that the Williams-Hazen predicted trends are applicable primarily to *large diameter mains* carrying *relatively inactive water*—and do not represent "average conditions."

QUALITY OF SUPPLY AND ITS EFFECT ON CAPACITY LOSS

The wide variation in rate of capacity loss found in different systems and the appreciable extent to which this loss progresses in a relatively short time in many systems, directs attention to probable causes of such loss. In collecting and reviewing the data, the Committee accordingly attempted to consider the quality of supply and effect thereof upon rate of capacity loss.

Alkalinity and carbon dioxide are believed to have an important effect on rate of capacity loss. Because of the inter-relation between alkalinity, carbon dioxide, and pH, this effect may be measured against the pH value alone.

The relation of pH to rate of capacity loss has been illustrated in the report by a diagram on which the percent of capacity loss in a fixed period, (30 years) in various supplies, has been plotted directly against the pH of the respective supplies.

The pronounced relation indicated by the data, showing the marked effect of pH on the relative rate of loss, may be summarized as follows:

pH VALUE OF SUPPLY	APPROXIMATE AVERAGE PER CENT CAPACITY LOSS IN TAR-COATED C. I. PIPE (IN 30 YEARS)
8.0	30
7.5	35
7.0	45
6.5	60
6.0	85

CAPACITY LOSS IN TAR COATED C. I. PIPE DUE TO SPECIAL CAUSES OTHER THAN TUBERCULATION

Although tuberculation is most frequently the cause of loss of capacity in tar coated cast iron mains, certain cases included in the Committee data afforded examples of capacity loss due to other special causes. In some instances the resulting trends of capacity loss were found to be quite similar to cases where loss was caused by tuberculation. Among special causes of capacity loss as classified were: incrustation, due to the precipitation on the pipe either of natural mineral content in the water, or of lime after water treatment; slime or fungus growth; and silting.

COEFFICIENT VALUES OF CEMENT-LINED PIPE

In addition to the main section of the report dealing with friction coefficients of tar-coated cast iron pipe, a number of related subjects involved in the general question of friction coefficients were presented.

Accordingly a second section of the report was devoted to coefficient values of cement-lined pipe.

The development of the centrifugal method of applying cement lining has inevitably resulted in the increased use of this type of lining as a method of preventing capacity loss. Available data upon the values of C for cement-lined pipe were found to be limited in scope and widely scattered in the literature. Accordingly, all available data were compiled and presented in order that this information might be made more readily available.

The Committee data indicated that the average value of C for new pipe, 4 to 24 inch in diameter with cement lining centrifugally applied, is 134, based on nominal diameter; and 150 based on actual net diameter.

These data also indicated that at least for mains 24 inch or less in diameter, the effect of lining thickness on diameter encroachment is sufficient to warrant considering values of C based both on nominal and on actual net diameter.

Other tests on pipe with cement linings not applied by centrifugal methods showed the following values: For pipe with natural or Rosendale cement lining tested both when new and at the end of approximately 10-year period, $C = 136$; for old style cement lined wrought iron pipe 12 and 14 inch diameter, after 41 years of service, $C = 104$.

Data relative to the value of cement lining in maintaining hydraulic capacity are extremely limited in scope. One line tested when new and again after six years of service showed no loss of capacity. Another line tested when new and after 1, 7, and 10 years of service also showed no tendency to decrease in carrying capacity with age. The data indicate that cement lining can be credited with a sustained capacity not attainable with ordinary type of tar coating.

COEFFICIENT VALUES OF PIPE WITH BITUMASTIC ENAMEL LINING CENTRIFUGALLY APPLIED

A third section of the report was devoted to a discussion of coefficient values with Bitumastic enamel lining applied by the centrifugal method. As in the case of cement lining, development of centrifugal methods of application have resulted in a greatly increased use of this type of lining to control capacity loss. Due to limited data available, results of all of the tests which have been conducted, together with a discussion of test methods, have been presented in the report. Results available include tests on 10-, 12-, and 20-inch cast iron pipe; and on 30-inch steel pipe.

The data indicate that coefficient values for new supply and transmission mains 16-inch in diameter and larger, with bitumastic enamel lining centrifugally applied may vary from $C = 145$ to $C = 160$ with an average value of $C = 155$; all based on nominal diameter.

These data also indicate that coefficient values for distribution mains less than 16-inch in diameter, with this type of lining, may vary from $C = 140$ to $C = 150$ with an average value of $C = 145$.

Bitumastic enamel lining is ordinarily applied with a thickness of

only 3/32-inch. Encroachment on diameter is accordingly small, as compared with other types of lining.

The first application of this type of lining was in 1931, and accordingly no data are available relative to its effectiveness in sustaining hydraulic capacity. The longest service period reported is two years, and the results of this test indicated no loss. The same material applied by the hand-brush method has been widely used for many years, and visual inspection of large pipe thus lined indicates that at least within periods of 16 years no apparent deterioration has occurred.

APPLICATION OF LININGS TO MAINS IN PLACE

While the foregoing methods of lining pipe provide methods of preventing or retarding capacity loss on new work, the question of restoration of capacity of many miles of mains already in place is of no less importance. The high cost of abandonment and duplication of existing mains, particularly under permanent pavements has directed attention to possible methods of reconditioning or lining existing mains in place, subsequent to cleaning.

Reference is made in one section of the report to available methods of lining mains in place.

Two methods have been devised in England for lining small diameter mains; the "Eric" process by which a bitumen lining is deposited electrically; and the Tate process, by which a cement-mortar lining is deposited in the pipe.

In this country, two methods have been developed for the reconditioning and lining of large diameter mains. On pipe lines sufficiently large to permit entry, the lines may be carefully cleaned and then treated with an application of hot bitumastic lining. A second method, which has recently been developed, involves the centrifugal application of a cement lining to large diameter mains in place. The lining is whirled into place by centrifugal force from a high speed centrifugal jet.

CORRECTIVE TREATMENT

In addition to the use of protective linings, chemical treatment of the water for reduction of corrosion has been adopted in recent years to abate the problem of capacity loss, and mention is made in the report, of some of the more important phases of corrective treatment.

Lime, sodium hydroxide and soda ash are among the alkalies used to reduce corrosion.

If water is maintained saturated with calcium carbonate, the water may be rendered practically non-corrosive to iron.

In maintaining adequate corrective treatment it is essential to maintain the treated water at or very near the saturation point, for super-saturation results in excessive deposits, and under-saturation causes the destruction of the needed protective film.

In corrective treatment, consideration must be given to the fact that the pH value at which saturation equilibrium occurs, varies with the characteristics of the water treated.

The calcium carbonate, or alkalinity of the water and the magnesium content are the most important factors. Saturation occurs at a pH of only 7.2 with an alkalinity of 190 ppm., whereas with water containing only 15 ppm. alkalinity, the pH must be raised to 9.3.

Accordingly, in planning corrective treatment, particular attention must be given to the characteristics of the water. The fact that a pH of 8.0 for example, is successful in controlling corrosion in one system, is no criterion as to the pH value that must be maintained with another supply.

RESTORATION OF CAPACITY OF UNLINED CAST IRON MAINS BY CLEANING

Cleaning of cast iron mains to restore capacity is an important consideration in the problem of capacity loss.

Two important phases of this question are discussed in the report; first, the immediate increase in coefficient values and consequent increase in capacity obtainable by cleaning; second, the rate of capacity loss subsequent to cleaning, or otherwise expressed, the maintenance of capacity after cleaning.

Data available to the Committee indicated that cleaning will ordinarily restore mains to approximately 85 percent of their original capacity. The average value of C in 24 tests was 39 before cleaning, and 104 after cleaning. If it is assumed that the value of C for new pipe was 125, the percentage of original capacity was accordingly 31 percent before, and 83 per cent after cleaning.

The period through which the relatively high capacity obtained immediately after cleaning is sustained, is subject to wide variations in individual cases. Some instances, particularly with small mains, are recorded, wherein the results of cleaning do not last more than

four or five months. In other instances the capacity is maintained at reasonably high values for substantial periods of time.

SUMMARY OF APPENDICES

All of the foregoing subjects deal directly with coefficients with tar-coated cast iron pipe, with the effect of age on coefficient values, or with alternate methods of retarding or preventing capacity loss.

Certain other subjects, while not directly concerned with these questions are, nevertheless, involved in the general question of pipe-line friction coefficients. Among these related subjects are coefficient values of steel and of concrete pipe.

COEFFICIENT VALUES OF STEEL PIPE

A discussion of coefficient values for steel pipe, due to the wide difference in interior surface with various methods of pipe construction, necessitates a definition of the several classes of steel pipe.

The classification of alternate types by Scobey in Bulletin 150 of the U. S. Dept. of Agriculture, provides a convenient standard for summarizing the values of C for various types of steel pipe when *new*.

The ordinary average values of Williams-Hazen C for various classes of *new* steel pipe may be summarized as follows:

Corrugated Pipe	*60*
Spiral Riveted Flow against Laps	*100*
Spiral Riveted Flow with Laps	*110*
Full Riveted	*115*
Girth Riveted	*130*
Continuous Interior Pipe	*139*

COEFFICIENT VALUES OF CONCRETE PIPE

Available data on concrete pipe indicate an extremely wide range in values of C, *with instances of values as low as C = 85 and as high as C = 152.* This wide range may be attributed not only to variation in surface texture or roughness of the pipe, but also to the relative uniformity of the pipe bore or, in other words, the presence or absence of undulations on the interior surface.

With these wide variations, particular care must be exercised in selecting values of C for concrete pipe.

Data available to the Committee indicate that the average value of C for the best grade, new, and large diameter precast reinforced concrete

pipe, carefully manufactured, may be assumed to approximate C = 150. On the other hand unless rigid metal forms, rich mix of concrete, careful curing and best workmanship throughout are employed, considerably lower values must be anticipated.

Values of C for concrete pipe of different classes and different methods of manufacture are presented in the report, these values being taken largely from a comprehensive paper by Fred C. Scobey, on this subject.

Tests on concrete pipe after substantial periods of service indicate that under normal conditions the initial capacity is relatively permanent.

SUMMARY

The vast financial loss resulting from rapid capacity reduction of pipe systems indicated by the data upon which the report was based, is a matter of major importance to the water works industry. It is believed of sufficient moment to warrant the determination, in each system, of the rate and cause of loss; as a basis for the adoption of the best preventive measures whether they are provision of permanent linings or corrective treatment of the supply.

Upon the basis of the average data on tar-coated Cast Iron Pipe, it is found that in 19 cities the average value of C after 30 years' service was 64, as compared with a value of 88 predicted in the Williamsr Hazen tables. Otherwise expressed the value of C dropped to 88 afte-only 11 years of service instead of after a predicted period of 30 years.

Furthermore, these average figures involve relatively large mains (20.5 inches average diameter). In 8 out of 10 systems the value of C for distribution mains after 30 years service was less than 50—involving a consequent loss of capacity of from 61.6 to 84 percent, as compared with a predicted loss of 37.5 percent.

The trend curves presented in the report, illustrate a wide range of loss of capacity in various systems, and the very considerable magnitude to which such loss develops within a comparatively short period in relation to the structural life of the pipe. It was the hope of the committee that these curves would serve to interest members of the water works industry in conducting and recording tests, in order that more selective numerical data might be ultimately made available to the profession.

With this thought in mind the following two recommendations were made by the committee.

1. *That the New England Water Works Association consider the formation of a Continuing Committee,*[1] *to cooperate, or to form joint committee, with the American Water Works Association, in order to extend the scope of this report.*
2. *That an endeavor be made to select typical pipe lines representative of the more important classifications of conditions, types and sizes of pipe, and that such lines be periodically tested to provide adequate data for the information of the profession.*

[1] *A. W. W. A. Committee Activities:*

A Committee of the American Water Works Association has recently been appointed with the following membership: Clinton L. Bogert, *Chairman*, James E. Gibson, Fred C. Scobey, Reeves J. Newsom, Thomas J. Skinker, Robert S. Weston.

The present objective of this Committee is to coöperate with the Committee of the New England Water Works Association in the publication of a supplementary report covering tests of wider geographical distribution. The success of this Joint Committee in making available adequate data, will depend upon the individual contribution of data, and the coöperation of all members solicited, in order that this objective may be reached.

The Committee of the New England Water Works Association has the following membership: Elson T. Killam, *Chairman*, Frank A. Barbour, W. W. Brush, Laurence C. Hough, Charles W. Sherman.

CONDITIONS OF MAINS IN TYPICAL AMERICAN CITIES

By Edgar K. Wilson

(*Chief Engineer, The Pitometer Company, Engineers, New York, N. Y.*)

This paper deals with observations of mains in typical American cities, which have been made during trunk main investigations and studies of distribution systems by the company with which the author is connected. To a considerable extent the paper has been suggested by and will endeavor to supplement the very valuable report of the Committee of the New England Water Works Association on "Pipe Line Friction Coefficients" presented in September, 1935. The investigations have almost entirely been based on measurement of velocity by Pitometers and of the loss of head by recording pressure gauges, the tests covering considerable lengths of pipe with valves, bends, and other specials included.

As in the New England Report the results will be grouped by sections of the country in an endeavor to show relations between the Williams and Hazen coefficient trend and the quality of water of each section. The Williams-Hazen trend curves have been extended as in the report mentioned to cover any range of ages thus far encountered.

While trend curves for the different local systems have been drawn, no attempt has been made to average the individual curves for any of the respective sections of the country; since such a practice is going ahead a little too fast with the information now at hand. If enough individual curves are made it is very easy to see whether the general trend is above or below the Williams-Hazen trend; and it is also possible to pick out the systems which have the same water characteristics as obtain in a locality where new work is to be designed.

Through the courtesy of the officials in many of the cities where the surveys have been made, permission has been granted to publish data, much of which has never before been issued in any form. In only a few cases has the information been presented under the name of the city where the work was done.

INSTRUMENTS AND METHODS

In practically all tests under consideration the lengths of pipe covered varied from about one-half to several miles in length. This prevented the use of manometer differential gauges, and the pressures maintained made it impossible to use mercury columns. For these reasons Bristol recording gauges were used for head determinations. The gauges are based on the Bristol Company's standard 0–150 feet head of water, 12-inch chart, which is divided to read 2 feet head of water and is easily read to 0.5 foot. By averaging over a given period mean readings are obtained for use in the computations.

Since the value of "C" depends directly upon the velocity, great care must be used in its measurement. Pitometers are inserted into the main at each end of the test section and constant readings are made throughout the test, from which average velocities are obtained.

Tests are made in duplicate, the gauges being interchanged; and after each test the gauges are calibrated by use of a dead weight tester.

The use of these instruments and methods has been quite satisfactory, always remembering that laboratory accuracy is neither possible nor necessary for the uses to which the results are to be put.

All data presented in this paper are from surveys made by the engineers of the Pitometer Company.

DISCUSSION OF RESULTS

There can be no disagreement with the principle that when vast sums of money have been and are being expended to lay water mains, it is most essential that this investment should be conserved to the highest possible degree. To do this it must be known, at least approximately, whether the mains are to lose only a small part or a considerable percentage of their carrying capacity in a given number of years. The usual practice of using a Williams-Hazen coefficient of 100 for new work recognizes the lack of knowledge of engineers in this important matter; and assumes that the main will lose almost a quarter of its new pipe value, probably at a not far distant date. For safety it may be necessary to do this, but it would be helpful to know as nearly as possible the length of time before this value of "C" will be reached. The exact length of service cannot be determined, but if the usual time is known in the general section with similar water supply a long step forward has been taken. A second step, even more important, is to know how this deterioration can be

TABLE 1

Williams-Hazen coefficients and ages of pipes—Eastern waters

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Cambridge, Mass. Total hardness 38. pH 8.75					
1	40	88	39		Steel riveted
2	40	91	39		Steel riveted
3	40	54	39		Steel riveted
3a, 5	40	67	39		Steel riveted
5	40	95	39		Steel riveted
15	40	102	39		Steel riveted
3b	30	23	29	91	
13	30	132	4	124	
4	24	74	68	65	
6	24	65	68	65	
11	24	85	40	81	
12	24	54	40	81	
16	24	72	61	69	
19	24	102	4	122	
20	24	61	60	69	
6	20	65	68	67	
7	20	102	39	81	
12	20	54	40	80	
16a	20	72	62	68	
8	16	117	2	126	
17a	16	59	35	83	
New England No. 1					
	20	109	12	109	
	20	122	4	122	
	20	123	2	126	
	16	118	13	107	
	14	108	33	85	
	14	68	9	112	
2	14	63	5	120	
	14	81	42	77	
1	12	76	44	75	
	12	101	36	81	
	12	89	17	100	
2a	10	70	27	88	
4	10	122	5	120	
6	10	85	15	103	
3	10	110	21	95	
6a	10	145	3	124	

TABLE 1—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
New England No. 1—*Concluded*					
7	10	106	41	75	
1a	8	73	27	87	
3a	8	52	26	88	
5	8	92	16	100	
7a	8	71	22	92	
2b	8	102	19	96	
4a	8	72	43	72	
5a	8	92	40	74	
8	8	78	43	72	
Worcester, Mass. Total hardness 13. pH 6.7					
1	48	102	15	105	
2	42	82	13	108	
4	36	91	13	108	
7	24	79	32	88	
8	24	69	30	90	
5	20	72	64	67	
9	20	70	30	88	
3	16	75	36	83	
6	16	94	19	99	
New England No. 3					
1	16	114	2	126	
2	16	67	36	83	
3	14	46	46	75	
4	12	80	34	83	
7	12	84	20	97	
8	12	90	32	85	
9	12	44	40	78	
5	10	52	37	78	
6	10	82	12	107	
11	10	73	25	90	
12	10	59	25	90	

TABLE 1—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Newton, Mass. Total alkalinity 81. Total hardness 29.9. pH 7.4					
7	20	66	13	108	All except one of these pipes had been cleaned a few years previous to the tests; but their capacity is impaired by a deposit thickest near the pump station and gradually diminishing as the distance increases. This deposit forms quite rapidly.
12	20	75	13	108	
18	20	105	13	108	
19	20	93	13	108	
20	20	105	13	108	
28	20	98	13	108	
1	16	60	13	108	
2	12	102	13	108	
4	12	90	13	108	
5	12	84	13	108	
6	12	73	13	108	
10	12	76	13	108	
11	12	84	13	108	
16	12	94	13	108	
17	12	92	20	96	
22	12	102	13	108	
23	12	72	13	108	
24	12	91	13	108	
25	12	77	13	108	
26	12	74	13	108	
27	12	81	13	108	
New England No. 4					
2	20	130	2	126	
6	16	117	14	106	
3	12	123	5	120	
4	12	67	19	98	
5	12	83	2	126	
Pawtucket, R. I.					
4	24	97	17	103	
9	24	89	50	75	
2a	20	90	19	100	
10	20	92	37	83	
New England No. 5					
	24	58	33	87	
	24	76	33	87	
	24	65	33	87	
	16	87	31	87	
	16	102	27	90	
	16	118	11	110	
	16	136	10	111	Probably cement lined

TABLE 1—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
			Elmira, N. Y.		
1	20	90	58	69	
2	20	86	58	69	
			Newark, N. J. Total alkalinity 20. pH 7.1		
7	36	76	13	108	
8	36	94	14	107	
15	36	112	11	111	
36	36	68	12	110	
38	36	85	29	92	
39	36	73	35	86	
3	30	61	50	76	
40	30	91	6	120	
1	24	55	60	69	
2	24	55	60	69	
6	24	40	57	71	
9	24	62	21	98	
11	24	88	36	84	
12	24	88	36	84	
13	24	56	36	84	
45	24	61	13	107	
22	20	42	12	109	
25	20	89	18	101	
31	20	69	68	67	
32	20	83	22	97	
35	20	47	32	87	
50	20	85	12	109	
6b	16	54	60	67	
			Maryland No. 1		
1	36	146	9		Concrete pipe
2a	36	15	19	101	Airbound
2c	36	116	19	101	Same pipe after air was released

Philadelphia, Pa.

Total alkalinity	Total hardness	Carbonate hardness	pH	
24	56			Torresdale
36	133			Upper Roxbury
43	129		7.2	Queen's Lane slow sand
38	132		6.9	Queen's Lane rapid sand
39	138		7.2	Belmont slow sand
40	140		7.1	Belmont rapid sand

TABLE 1—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
			Philadelphia, Pa.—*Continued*		
215	60	98	19		Steel
216	60	99	19		Steel
217	60	86	19		Steel
14	48	110	12	110	
24	48	90	12	110	
35	48	85	40	84	
56	48	94	19	101	
56a	48	85	19	101	
109	48	92	42	82	
134	48	76	32	89	
142	48	84	30	91	
143	48	81	30	91	
149	48	80	36	86	
178	48	104	19	101	
181	48	88	18	102	
183	48	92	18	102	
187	48	99	19	101	
194	48	110	19	101	
195	48	110	19	101	
200	48	108	18	102	
201	48	116	18	102	
204	48	94	19	101	
218	48	103	32	89	
220	48	101	32	89	
220a	48	74	32	89	
222	48	82	27	93	
267	48	94	26	94	
270	48	132	1	134	
272	48	104	19	101	
47	36	116	1	128	
70	36	105	4	124	
77	36	61	56	73	
96	36	71	34	87	
118	36	134	1	134	
133	36	86	35	86	
178	36	86	40	83	
6	30	104	33	88	
30	30	78	35	86	
50	30	58	76	62	
61	30	71	25	95	
69	30	56	47	77	

TABLE 1—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
			Philadelphia, Pa.—*Continued*		
78	30	89	40	82	
89	30	82	49	76	
96	30	71	34	87	
107	30	92	34	87	
184	30	76	39	83	
205	30	75	27	93	
221	30	89	49	76	
233	30	79	24	96	
235	30	78	13	109	
237	30	85	17	103	
239	30	61	26	94	
266	30	75	39	83	
280	30	117	24	96	
286	30	105	33	88	
291	30	74	37	85	
367	30	136	3	135	
67	24	140	1	138	
238	24	105	17	103	
320b	24	126	4	122	
355	24	130	1	128	
8	20	104	33	86	
11	20	113	27	91	
15a	20	73	46	78	
42	20	72	97	54	
55	20	88	11	110	
57	20	82	33	86	
58	20	90	24	95	
66	20	91	107	52	
71	20	82	33	86	
73	20	94	22	97	
79	20	64	33	86	
128	20	92	35	84	
191	20	60	11	110	
245	20	95	23	96	
248	20	53	35	84	
251	20	79	22	97	
269	20	130	5	120	
283	20	85	19	100	
285	20	82	30	88	
288	20	70	35	84	
292	20	79	37	83	

TABLE 1—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
			Philadelphia, Pa.—*Concluded*		
322	20	75	26	92	
350	20	83	59	69	
4	16	85	29	89	
5	16	113	32	86	
7	16	89	53	72	
16	16	94	30	88	
23	16	57	53	72	
26	16	85	67	61	
28	16	67	38	81	
59	16	64	42	78	
137	16	104	6	118	
138	16	130	1	128	
145	16	65	24	94	
150	16	118	6	118	
234	16	131	1	128	
254	16	117	1	128	
255	16	72	17	102	
258	16	46	29	89	
273	16	95	16	103	
278	16	113	20	98	
279	16	88	19	99	
284	16	73	55	70	
352	16	99	4	122	
354	16	73	41	79	
359	16	99	1	128	
368	16	124	3	124	
1	12	56	15	105	
2	12	85	9	113	
			Baltimore, Md. Total alkalinity 41. Total hardness 50		
L14	60	120	10	113	
L11a	48	114	10	113	
L17a	48	102	45	80	
L17b	48	81	45	80	
M14b	48	102	12	110	
L1	40	87	45	78	
L2	40	71	45	78	
L3	40	71	44	80	
L4	40	93	44	80	
L7	40	91	45	78	

TABLE 1—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Baltimore, Md. Total alkalinity 41. Total hardness 50—*Continued*					
L8	40	108	45	78	
L9	40	118	45	78	
L18	40	85	12	110	
L18b	40	98	12	110	
L19	40	98	8	116	
L29	40	92	26	94	
L11b	36	61	10	113	
L11c	36	68	10	113	
L16	36	99	25	95	
L21	36	130	36	86	
L22	36	110	36	86	
L31a	36	91	25	95	L31a and L31b are parallel mains
L31b	36	91	25	95	
M1	36	74	26	94	
M2	36	82	26	94	
M3a	36	38	11	111	
M3b	36	109	11	111	
M5	36	72	11	111	
M10	36	73	27	93	
M13b	36	93	14	107	
H14	36	82	1	128	
H15	36	129	4	124	
L6	30	90	6	120	
L10	30	98	25	95	
L12	30	87	15	106	
L13	30	59	10	113	
L15b	30	110	25	95	
L23	30	106	26	94	
L24	30	116	10	113	
L25a	30	31	16	104	
L25b	30	30	16	104	
L26a	30	107	33	88	
L26b	30	102	33	88	
L27	30	62	24	96	
L28	30	44	13	109	
L28a	30	49	13	109	
L30	30	63	25	95	
L32	30	116	13	109	
L33	30	74	26	94	
M4	30	74	11	111	
M7a	30	60	26	94	

TABLE 1—*Concluded*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Baltimore, Md. Total alkalinity 41. Total hardness 50—*Concluded*					
M7b	30	75	26	94	
M8	30	105	25	95	
M9	30	79	11	111	
M11	30	91	12	110	
M12	30	115	13	109	
M13a	30	73	14	107	
M15	30	100	20	99	
H1	20	117	1	128	
H6	20	108	27	91	
H7	20	83	26	92	
H11	20	132	28	90	
H17a	20	80	2	126	
H17b	16	104	2	126	

retarded or eliminated by use of various pipe linings or by the treatment of the water.

There is one prevalent idea, however, which should be eliminated from our minds at the outset. Because a pipe has closely followed the Williams-Hazen timetable for 30 or 40 years does not mean that the pipe is by any means perfect. It still has a seriously impaired capacity; and the only way to restore it to anywhere near its original value is by reducing the roughness of the interior so that friction will be diminished.

It is hoped at a not too distant date that a sufficient number of tests on each size of pipe may be obtained in a given section of the country, so that a trend for each size may be worked out. As this ideal has not yet been attained the author has divided the range of sizes from 10 to 60 inches into three groups, each of which at coefficient 80 in the Williams-Hazen tables varies by about two years. A few 8-inch tests have been included in the lower group. The Williams-Hazen trend curves are shown in each chart by a heavy line.

Since the term "supply main" is entirely relative, depending on the size of the system served, and since tests of mains 12 inches and smaller have not been particularly numerous, they will be considered with the pipes of larger size without the division made in the report, of supply and distribution mains divided at the 16-inch size.

To follow the nomenclature of the New England report the data

TABLE 2

Williams-Hazen coefficients and ages of pipes—Great Lakes Basin

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Cleveland, Ohio. Total alkalinity 85. Total hardness 114. Carbonate hardness 29. pH 7.5					
L82	60	115	7		Steel
L83	60	117	7		Steel
L1	48	116	7	118	
L10	48	88	32	88	
2-2	48	128	5	122	
L16	42	98	33	88	
L24	42	97	33	88	
L2	36	90	47	78	
L25	36	104	16	105	
L29	36	87	38	84	
L32	36	95	38	84	
L42	36	107	8	116	
L47	36	107	7	117	
L56	36	114	5	122	
1-20	36	103	15	106	
1-22	36	114	7	117	
1-28	36	125	5	122	
L7	30	89	42	81	
L63	30	98	45	78	
1-2	30	109	47	77	
1-3	30	117	6	120	
1-15	30	110	34	87	
1-18	30	98	30	90	
1-21	30	79	30	90	
1-30	30	92	34	87	
2-1	30	102	25	95	
2-7	30	116	12	110	
2-11	30	100	14	107	
L24	24	87	57	70	
L44	24	73	26	93	
1-11	24	104	19	100	
1-12	24	71	25	94	
1-24	24	124	14	106	
1-25	24	120	3	124	
1-35	24	114	7	117	
1-33	20	140	5	120	
L34	16	78	36	83	
L37	16	87	37	82	
L51	16	104	11	110	

TABLE 2—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Cleveland, Ohio. Total alkalinity 85. Total hardness 114. Carbonate hardness 29. pH 7.5—*Concluded*					
1-32	16	130	6	118	
2-3	16	90	25	92	
2-6	16	95	12	108	
2-8	16	111	24	94	
2-9	16	106	19	99	
2-12	16	122	19	99	
2-15	16	138	9	113	
Watertown, N. Y. Total alkalinity 30. Total hardness 40. pH 7.4					
2	24	81	22	97	
1	16	82	48	75	
3	16	94	52	72	
Toledo, Ohio. Total hardness 253					
10	30	120	9	115	
17a	30	102	6	120	
17b	30	109	6	120	
19	30	84	30	90	
21	30	86	30	90	
25	30	86	30	90	
28a	30	89	12	110	
28b	30	83	12	110	
1	24	125	6	118	
12a	24	95	9	113	
12b	24	132	1	128	
14a	16	127	1	128	
14b	16	133	1	128	
15	16	129	2	126	
2	12	84	20	97	
3	12	127	10	110	
4	12	123	10	110	
5	12	89	16	102	
7a	12	107	5	120	
8	12	132	5	120	
9	12	88	52	69	
13b	12	128	4	122	
18	12	119	2	126	
23	12	123	3	124	
24	12	121	4	122	

TABLE 2—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Toledo, Ohio. Total hardness 253—*Concluded*					
26	12	103	10	110	
27	12	100	10	110	
29	12	123	4	122	
33	12	99	10	110	
36	12	115	38	79	
Buffalo, N. Y. Total hardness 170. Carbonate hardness 138					
1	48	113	26	94	
1b	48	113	26	94	
2	48	118	26	94	
2b	48	88	26	94	
8	48	91	40	83	
3	36	129	6	120	
6	36	100	35	87	
6b	36	100	35	87	
7a	36	99	51	77	
7b	36	99	51	77	
8a	36	122	19	101	
10	36	110	48	78	
11	36	93	48	78	
14	36	103	62	72	
15	36	132	28	92	Very high velocity
15a	36	103	28	92	
18	36	74	18	102	
18a	36	103	11	112	
26	16	106	43	82	
Detroit, Mich. Total alkalinity 77.9. Total hardness 97.6. Carbonate hardness 78. pH 7.6					
2	42	140	47	79	
3	42	112	53	75	
4	42	132	33	88	
5	30	113	48	77	
5a	30	81	48	77	
10	30	84	48	77	
11	30	132	38	84	
6	24	105	72	64	
12	24	88	56	71	
17	16	71	38	81	
18	16	96	38	81	
20	16	86	38	81	

TABLE 2—*Concluded*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
			New York No. 1		
7	24	105	23	95	
1	20	104	23	96	
2	20	84	23	96	
3	20	92	23	96	
4	20	101	23	96	
5	20	94	23	96	
6	20	72	23	96	
Windsor, Ontario. Total alkalinity 90. Total hardness 102.6. Carbonate hardness 90					
1	20	134	12	109	
2	16	94	30	88	
			New York No. 2		
1	30	130	28		Lockbar steel
2	24	86	28	91	
3	12	95	23	94	
5	12	98	21	96	
6	12	83	21	96	
7	12	112	8	114	
4	10	94	21	96	

will be presented under the same classifications, namely, Eastern, Great Lakes, and Mississippi Basin. To these have been added Texas and Miscellaneous. For Philadelphia, where a sufficient number of tests have been made, separate charts are presented, but the data are listed under "Eastern Waters."

Figure 1 shows tests on large pipes in the eastern section of the country. As will be seen, only a few tests on these large sizes have been made, and trend curves are indefinite.

Figure 2 shows tests on 20- to 30-inch pipes, and apparently bears out the conclusion that New England waters are hard on the carrying capacities of pipes.

Figure 3 for smaller pipes shows the same tendency.

Figure 4 of large mains in Philadelphia, however, shows a trend very close to the Williams-Hazen trend curve, and this is also indicated in figure 5.

TABLE 3

Williams-Hazen coefficients and ages of pipes—Mississippi Basin

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
St. Louis, Mo. Total alkalinity 40. Total hardness 98. Carbonate hardness 40. pH 9.1					
L3	36	78	58	72	
L4	36	72	56	74	
L5a	36	112	14	107	
L5b	36	101	14	107	
L6	36	96	28	92	
L12	36	124	14	107	
L15	36	125	14	107	
L19	36	127	12		Sleel pipe
L20	36	134	12		Steel pipe
L43	36	98	14	107	
L44	36	91	14	107	
L52	36	106	14	107	
L53	36	76	14	107	
L54	36	97	14	107	
H1	36	96	27	93	
H2	36	85	27	93	
H3	36	109	27	93	
H4	36	80	27	93	
H5	36	79	27	93	
H6	36	78	27	93	
H7	36	90	25	95	
H9a	36	104	16	105	
H9b	36	112	21	99	
H11	36	84	31	89	
H12	36	86	31	89	
H14	36	127	14	107	
H17	36	125	14	107	
H31	36	85	20	100	
H36a	36	87	26	94	
H36b	36	87	32	89	
H37	36	96	31	89	
H44	36	118	13	108	
L16	30	99	14	107	
L23	30	116	16	104	
L32	30	105	44	79	
H10	30	74	32	88	
H19	30	108	20	99	
H21	30	79	33	88	
H23	30	81	33	88	

TABLE 3—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
St. Louis, Mo. Total alkalinity 40. Total hardness 98. Carbonate hardness 40. pH 9.1—*Continued*					
H25	30	83	33	88	
H26	30	87	32	88	
H28	30	91	31	89	
H39	30	77	20	99	
H40	30	71	32	88	
H42	30	79	31	89	
H43	30	91	35	86	
H45	30	87	43	80	
H56	30	70	32	88	
L7	20	117	28	90	
L8	20	120	16	104	
L9	20	100	15	105	
L10	20	118	16	104	
L11	20	123	14	106	
L13	20	130	16	104	
L14	20	110	15	105	
L22	20	114	16	104	
L24	20	98	21	98	
L25	20	104	21	98	
L26	20	109	20	99	
L27	20	92	34	85	
L28	20	73	34	85	
L30	20	116	22	97	
L33	20	113	14	106	
L34	20	95	27	91	
L37	20	111	14	106	
L38	20	105	14	106	
L40	20	100	16	104	
L42	20	83	17	103	
L45	20	125	16	104	
L46	20	102	15	105	
L47	20	100	16	104	
L48	20	85	16	104	
L49	20	85	16	104	
L50	20	100	16	104	
L55	20	73	39	82	
L56	20	93	14	106	
L60	20	112	16	104	
L61	20	114	16	104	
L64	20	115	15	105	

TABLE 3—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
St. Louis, Mo. Total alkalinity 40. Total hardness 98. Carbonate hardness 40. pH 9.1—*Concluded*					
L73	20	98	15	105	
L75	20	125	14	106	
L76	20	100	26	92	
H8	20	107	24	94	
H15	20	130	15	105	
H16	20	144	35	84	
H22	20	111	11	110	
H39	20	108	18	101	
H32	20	92	20	99	
H33	20	124	2	126	
H34	20	86	26	92	
H38	20	114	20	99	
H36	20	96	39	82	
H47	20	85	43	79	
H48	20	73	38	83	
H49	20	76	43	79	
H50	20	109	26	92	
H53	20	89	36	84	
H54	20	56	36	84	
H57	20	95	32	87	
H59	20	106	29	89	
H63	20	135	1	128	
L21	15	103	42	78	
L29	15	77	22	95	
L58	15	110	21	96	
L70	15	81	50	72	
L71	15	50	50	72	
Cincinnati, Ohio. Total alkalinity 36. Total hardness 113. Carbonate hardness 36. pH 8.5					
1-82	60	121	22	98	
1-1	48	118	16	105	
1-2	48	117	23	97	
1-84	42	95	24	96	
1-49	36	94	46	79	
1-50	36	66	46	79	
1-80	36	127	15	106	
1-89	36	66	53	75	
1-90	36	39	57	72	

TABLE 3—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Cincinnati, Ohio. Total alkalinity 36. Total hardness 113. Carbonate hardness 36. pH 8.5—*Continued*					
1-8	30	124	4	122	
1-10	24	111	22	97	
1-14	24	126	2	126	
1-34	24	106	6	118	
1-42	24	129	25	94	
1-61	24	106	16	104	
1-62	24	98	16	104	
1-67	24	144	1	138	
1-111	24	76	17	103	
1-33	20	114	5	120	
1-107	20	68	52	73	
1-21	16	99	22	96	
1-21a	16	116	16	103	
1-22	16	116	15	105	
1-25	16	96	15	105	
1-29	16	125	2	126	
1-32	16	108	5	120	
1-65	16	127	4	122	
1-69	16	112	2	126	
1-116	16	103	36	83	
1-117	16	106	41	79	
1-15	12	118	25	91	
1-77	12	113	19	98	
2-1	48	97	21	99	
2-2	48	103	28	92	
2-49	36	94	51	75	
2-50	36	98	51	75	
2-8	30	114	9	115	
2-10	24	114	28	91	
2-14	24	121	6	118	
2-34	24	130	11	110	
2-42	24	87	30	89	
2-67	24	128	5	120	
2-56b	24	137	1	138	
2-33	20	116	10	111	
2-45	20	86	30	88	
2-21a	16	106	27	90	
2-21b	16	116	21	97	
2-22	16	108	20	98	
2-29	16	117	7	117	

TABLE 3—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Cincinnati, Ohio. Total alkalinity 36. Total hardness 113. Carbonate hardness 36. pH 8.5—*Concluded*					
2-32	16	107	10	111	
2-65	16	105	9	113	
2-65a	16	122	1	128	
2-69	16	115	7	117	
2-15	12	127	30	86	
2-20	12	68	24	92	
2-68	12	74	45	74	
Minneapolis, Minn. Total hardness 171.7					
7	60	116	8		Lock bar steel
2	54	103	22		Lock bar steel
1	50	93	38		Riveted steel
3	50	118	38		Riveted steel
4	48	114	22		Lock bar steel
6	48	123	5		Lock bar steel
8	48	116	8		Lock bar steel
16	42	136	3		Lock bar steel
12	36	83	20		Lock bar steel
30	36	106	48	78	
34	36	97	25	95	
74	30	108	31	89	
13	24	103	20	99	
26	24	112	7	117	
36	24	107	47	77	
42	24	78	41	81	
43	24	102	23	96	
50	24	79	34	86	
52	24	97	20	99	
79	24	106	26	93	
40	16	81	47	75	
45	16	104	34	85	
51	16	90	5	120	
60	16	115	19	99	
69	16	86	39	80	

TABLE 3—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
St. Paul, Minn. Total alkalinity 150. Total hardness 168. Carbonate hardness 149. pH 7.0					
33a	42	100	23	96	
13	36	79	39	83	
33b	36	101	23	97	
10	30	97	51	75	
11	30	108	11	111	
14	30	108	40	81	
34a	30	100	23	98	
34b	30	106	23	98	
36	30	108	12	110	
15	24	92	51	74	
17	24	108	47	77	
25	24	96	14	106	
1	20	109	47	76	
2	20	109	50	74	
13a	20	95	51	73	
23	20	98	49	74	
47	20	104	47	76	
3	16	88	50	73	
4	16	108	47	75	
6	16	77	47	75	
19	16	95	46	76	
21	16	91	49	74	
22	16	99	51	73	
28	16	99	49	74	
31	16	107	28	89	
51	16	87	26	91	
Pittsburgh, Pa. Total hardness 70					
79	60	73	34	88	
24	50	85	22		Steel
42	42.5	91	29	91	
3	36	71	30	100	
41	36	53	28	92	
43	36	93	45	79	
49	36	74	29	91	
50	36	72	28	92	
86	36	88	25	95	
1	30	82	34	87	
2	30	67	56	72	
7	30	72	40	82	
10	30	66	22	97	

TABLE 3—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
		Pittsburgh, Pa. Total hardness 70—*Concluded*			
52	30	53	48	77	
67	30	44	17	103	
73	30	110	1	128	
29	24	71	39	83	
96	24	122	2	126	
4a	20	65	20	99	
4b	20	123	2	126	
6	20	100	34	85	
16	20	73	34	85	
25	20	83	14	106	
28	20	85	15	105	
34	20	74	34	85	
46	20	79	60	68	
72	20	78	20	99	
97	20	74	14	106	
21a	16	93	14	106	
21b	16	108	14	106	
9	15	66	58	68	
33	15	44	58	68	
18	12	46	47	73	
30	12	102	39	78	
31	12	92	28	88	
63	12	70	26	90	
78	12	72	20	97	
		Ohio No. 1			
1a	30	80	46	78	
3	30	65	46	78	
4	30	57	46	78	
4a	30	58	46	78	
4b	30	53	46	78	
4c	30	57	46	78	
2	24	138	1	138	
5a	24	57	19	100	
5b	24	74	19	100	
7	24	75	19	100	
9	24	80	46	77	
10	20	88	10	111	
11	20	59	46	76	
13	20	46	46	76	
12	16	62	46	76	
14	12	61	3	124	
15	12	81	13	106	

TABLE 3—*Continued*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Columbus, Ohio. Total alkalinity 35. Total hardness 91. Carbonate hardness 35. pH 9.2					
1	36	56	17	103	
5	36	53	16	105	
13	36	101	5	122	
89	36	61	21	99	
90	36	58	21	99	
17	30	82	5	122	
19	24	62	9	113	
24	24	70	15	105	
57	24	56	27	92	
59	24	53	37	84	
64	24	65	14	106	
71	24	60	22	97	
74	24	80	8	115	
88	24	58	47	77	
3	20	66	14	106	
4	20	71	14	106	
80	20	48	25	93	
87	20	52	56	70	
2	16	54	17	102	
26	16	105	15	105	
47	16	58	41	79	
51	16	60	41	79	
79	16	63	25	92	
7	12	47	33	84	
44	12	74	7	116	
49	12	96	12	107	
78	12	84	25	91	
Dayton, Ohio. Total hardness 362. Carbonate hardness 280. pH 7.2					
3	24	123	12	109	
6	20	111	24	95	
Kansas City, Mo. Total hardness 215. Carbonate hardness 150					
11	30	99	17	103	
12	24	98	21	98	
13	24	104	14	106	
21	24	102	15	105	
22	24	128	1	128	
23	24	95	15	105	

TABLE 3—*Concluded*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Kansas City, Mo. Total hardness 215. Carbonate hardness 150—*Concluded*					
4	20	97	12	109	
5	20	101	21	98	
5a	20	102	21	98	
23b	16	90	17	102	
24	16	98	15	105	
25	16	97	9	113	
26	16	88	15	105	
27	16	102	15	105	
New Orleans, La. Total alkalinity 41. pH 7.9					
1a	48	103	27	93	
1b	48	103	27	93	
2	43.31	124	10		Steel
27	42	108	24	96	
4	30	99	22	97	
6a	30	99	27	93	
6b	30	99	27	93	
28	30	111	24	96	
31	30	107	24	96	
32a	30	93	24	96	
32b	30	99	24	96	
22	24	104	28	91	
53a	24	87	26	93	
53b	24	90	26	93	
72a	24	87	24	95	
72b	24	90	24	95	
8	20	98	27	91	
12	20	95	27	91	
20	20	102	25	93	
24	20	91	26	92	
26	20	110	24	94	
33	20	105	5	93	
36a	20	113	24	94	
36b	20	108	24	94	
39a	20	103	25	93	
39b	20	109	25	93	
40	20	106	28	90	
9	16	110	27	90	
10	16	81	27	90	
47	16	110	24	94	
49a	16	95	24	94	
49b	16	96	24	94	

TABLE 4

Williams-Hazen coefficients and ages of pipes—Texas and miscellaneous

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Waco, Texas. Total hardness 135					
2	24	79	16	104	
1	20	122	16	104	
4	16	80	16	103	
9	16	97	15	105	
5	12	72	37	81	
7	12	73	31	86	
8	12	104	13	106	
10	12	98	15	103	
12	12	88	31	86	
3	10	74	37	78	
6	10	56	37	78	
11	10	75	30	85	
Texas No. 1					
37a	36	112	36	86	
37b	30	112	36	85	
37c	24	112	36	84	
1	20	139	1	138	
13a	20	127	6	118	
36	20	148	6	118	
13b	18	127	6	118	
33	18	70	33	85	
27b	18	123	3	124	
8	16	135	5	130	
19	16	105	6	118	
27a	16	123	3	124	
4a	12	84	13	106	
4b	12	84	20	97	
5	12	75	4	122	
6	12	125	3	124	
9	12	112	36	81	
11	12	91	3	124	
15	12	82	15	103	
20	12	117	6	118	
22a	12	95	15	103	
23	12	132	2	126	
25	12	135	11	108	
26	12	129	11	108	
27c	12	123	3	124	
28a	12	82	28	88	
30	12	99	43	76	
31	12	52	43	76	

TABLE 4—*Concluded*

TEST NUMBER	SIZE, INCHES	COEFFICIENT BY TEST	AGE, YEARS	COEFFICIENT BY TABLES	REMARKS
Texas No. 1—*Concluded*					
34	12	106	6	118	
2	10	112	5	120	
3	10	132	2	126	
7	10	110	6	118	
10	10	143	1	138	
14	10	113	36	79	
14a	10	100	15	103	
17	10	98	36	79	
18	10	69	13	106	
22b	10	95	15	103	
24	10	106	5	120	
28b	10	82	28	87	
32	10	113	8	114	
35	10	96	2	126	
Austin, Texas. Total alkalinity 44. Total hardness 69. Carbonate hardness 44. pH 9.3					
3	20	93	14	106	
1	12	100	38	79	
2	12	103	48	72	
5	12	121	38	79	
Texas No. 2					
1	20	122	3	124	
4	20	80	8	115	
3a	18	111	8	115	
3b	18	114	8	115	
Virginia, Minn. Total alkalinity 147. Total hardness 143. Carbonate hardness 143					
2	12	116	11	108	
1	10	60	23	92	
3	10	114	10	110	
4	8	89	29	84	
6	8	54	33	80	
Boulder, Col. Total hardness 13.9					
5	17.5	74	29		Steel
7	11.5	74	29		
2	16	65	30	88	
3	12	105	11	108	

TABLE 5

Pipes laid 1880–1890 inclusive

TEST NUMBER	SIZE, INCHES	DATE LAID	COEFFICIENT BY TEST	COEFFICIENT BY TABLES
		Philadelphia, Pa.		
35	48	1886	85	83
109	48	1884	92	82
149	48	1890	80	86
178	36	1886	86	83
78	30	1886	89	82
184	30	1887	76	83
266	30	1887	75	83
291	30	1889	74	85
15a	20	1880	73	78
292	20	1889	79	83
28	16	1888	67	82
59	16	1884	64	78
354	16	1885	73	79
		Columbus, Ohio		
59	24	1887	53	83
88	24	1888	58	76
47	16	1888	58	79
51	16	1888	41	79
		Pittsburgh, Pa.		
43	36	1884	93	80
7	30	1889	72	82
52	30	1881	53	76
29	24	1890	71	83
18	12	1882	46	71
30	12	1890	102	78
		St. Louis, Mo.		
L32	30	1884	105	79
H45	30	1885	87	79
L55	20	1889	73	81
H46	20	1889	96	81
H47	20	1885	85	79
H48	20	1889	73	82
H49	20	1885	76	79
L21	15	1886	103	77

TABLE 5—*Continued*

TEST NUMBER	SIZE, INCHES	DATE LAID	COEFFICIENT BY TEST	COEFFICIENT BY TABLES
		Cincinnati, Ohio		
49-1	36	1884	94	79
49-2	36	1884	94	75
50-1	36	1884	66	79
50-2	36	1884	98	75
117	16	1889	106	76
68	12	1890	74	73
		Minneapolis, Minn.		
36	24	1880	107	77
40	16	1888	81	75
		St. Paul, Minn.		
10	30	1884	97	75
15	24	1884	92	74
17	24	1888	108	77
1	20	1888	109	77
2	20	1885	109	73
13a	20	1884	95	73
23	20	1886	98	76
47	20	1888	104	77
3	16	1885	88	73
4	16	1888	108	75
6	16	1888	77	75
19	16	1889	95	76
21	16	1886	91	74
22	16	1884	99	72
28	16	1886	99	74
		Cleveland, Ohio		
L2	36	1883	90	78
L7	30	1888	89	81
L63	30	1885	98	78
1-2	30	1883	109	81
		Detroit, Mich.		
2	42	1881	140	79
5	30	1880	113	77
5A	30	1880	81	77
10	30	1880	84	78

TABLE 5—*Concluded*

TEST NUMBER	SIZE, INCHES	DATE LAID	COEFFICIENT BY TEST	COEFFICIENT BY TABLES
Detroit, Mich.—*Concluded*				
11	30	1890	132	84
17	16	1890	71	80
18	16	1890	96	80
20	16	1890	86	80
Toledo, Ohio				
36	12	1888	115	80
Watertown, N. Y.				
1	16	1880	82	76
Buffalo, N. Y.				
7A	36	1885	99	77
7B	36	1885	99	77
10	36	1888	110	78
11	36	1888	93	78

Figure 5 shows results of tests on mains from 20 to 30 inches. It will be noted in this chart that pipes of 97 and 107 years in age were tested and that these pipes showed remarkably high coefficients for their age.

Figure 6, a chart of pipes 10 to 18 inches, indicates a trend somewhat below the Williams-Hazen curve, but insufficient points render this curve unreliable.

Figure 7 shows results of tests on the largest mains in the Great Lakes Basin. The coefficients, especially for Buffalo, show considerably higher trend than those of Eastern waters.

Figure 8 in general indicates similar conditions.

Figure 9 for pipes smaller than 18 inches shows all trends closely following the Williams-Hazen trend curve.

In the Mississippi Basin charts, of which figure 10 includes the largest pipes, the cities on the tributaries of the Ohio River show low trends, except for Cincinnati. It will be noticed in figure 10, and to a greater extent in figure 11, that at about the fifty year mark there is a decidedly high group of coefficients marked by small squares which represent tests made in St. Paul and Minneapolis. These

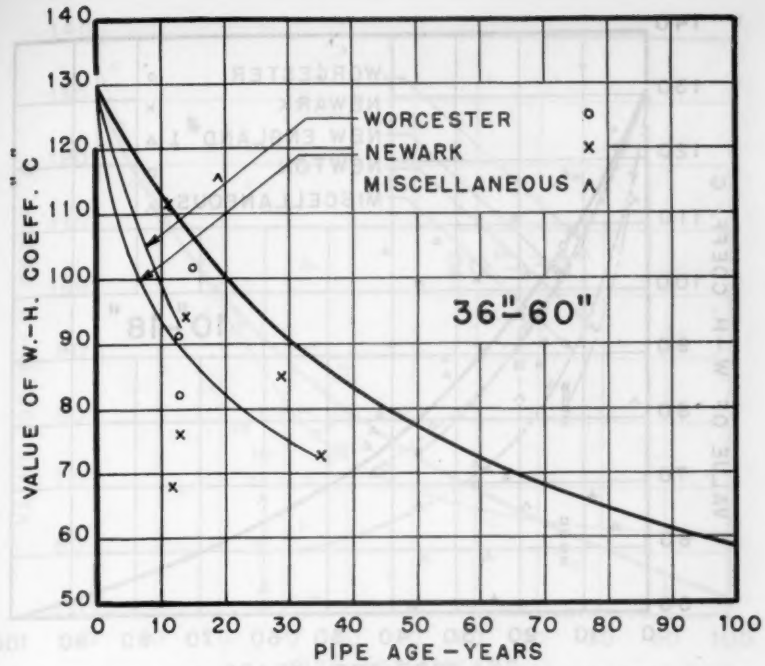

FIG. 1. TRENDS OF AGE-COEFFICIENT RELATION FOR 36- TO 60-INCH PIPES—EASTERN WATERS

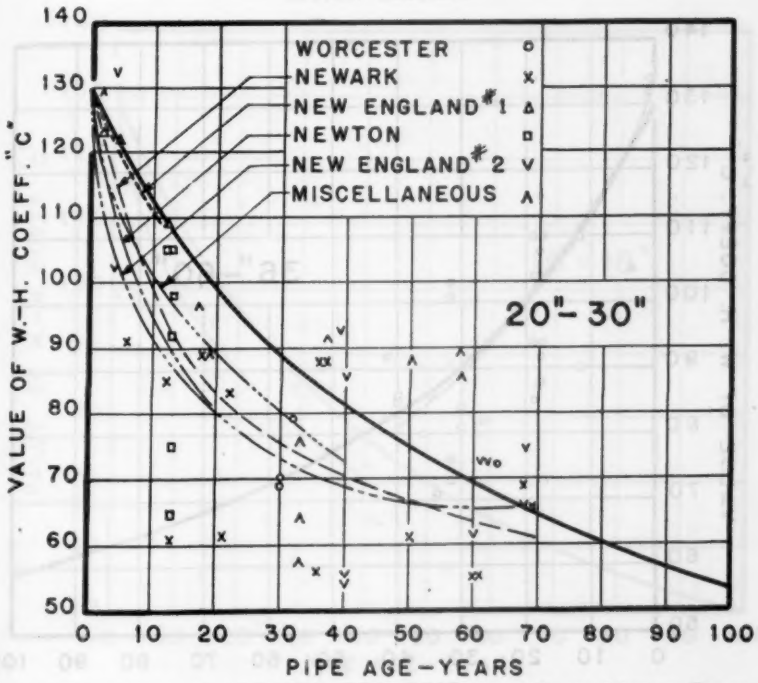

FIG. 2. TRENDS OF AGE-COEFFICIENT RELATION FOR 20- TO 30-INCH PIPES—EASTERN WATERS

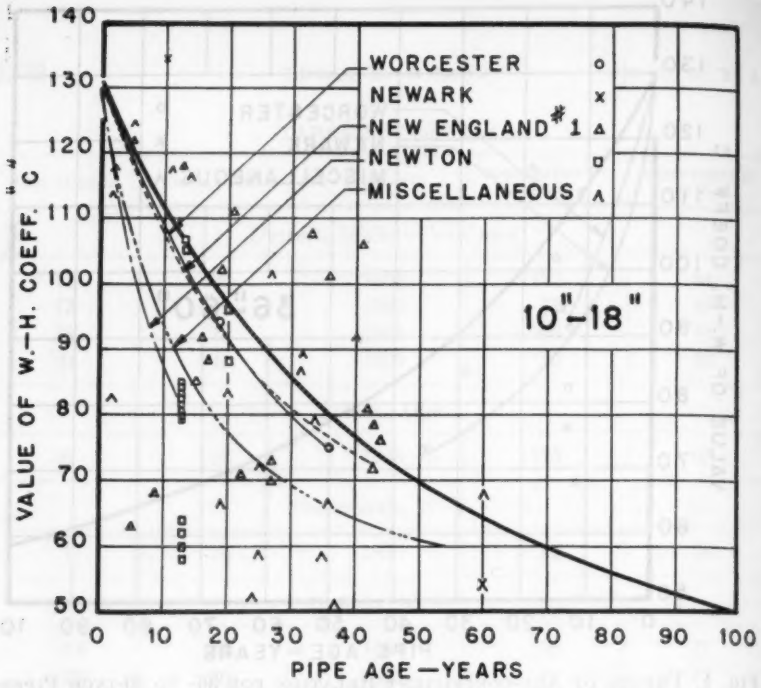

FIG 3. TRENDS OF AGE-COEFFICIENT RELATION FOR 10- TO 18-INCH PIPES—EASTERN WATERS

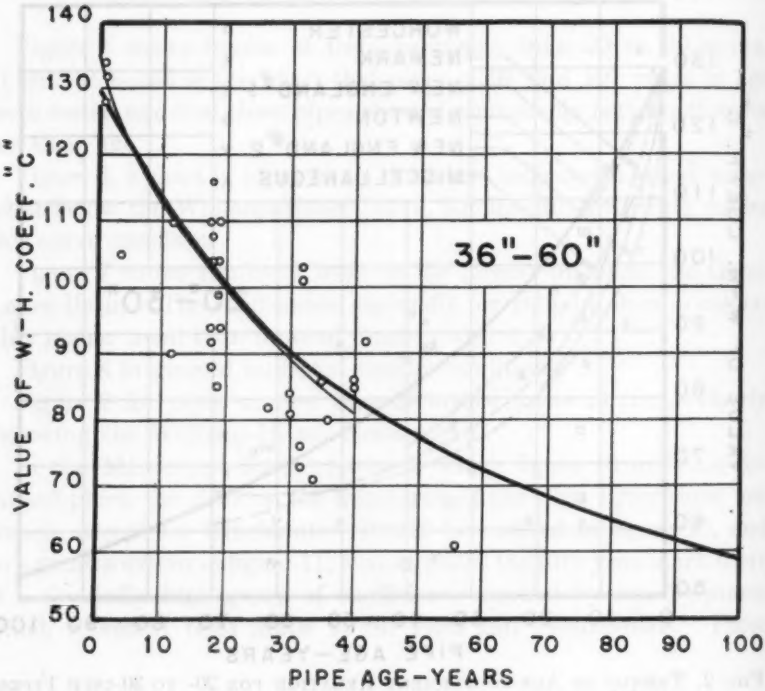

FIG. 4. TRENDS OF AGE-COEFFICIENT RELATION FOR 36- TO 60-INCH PIPES—PHILADELPHIA

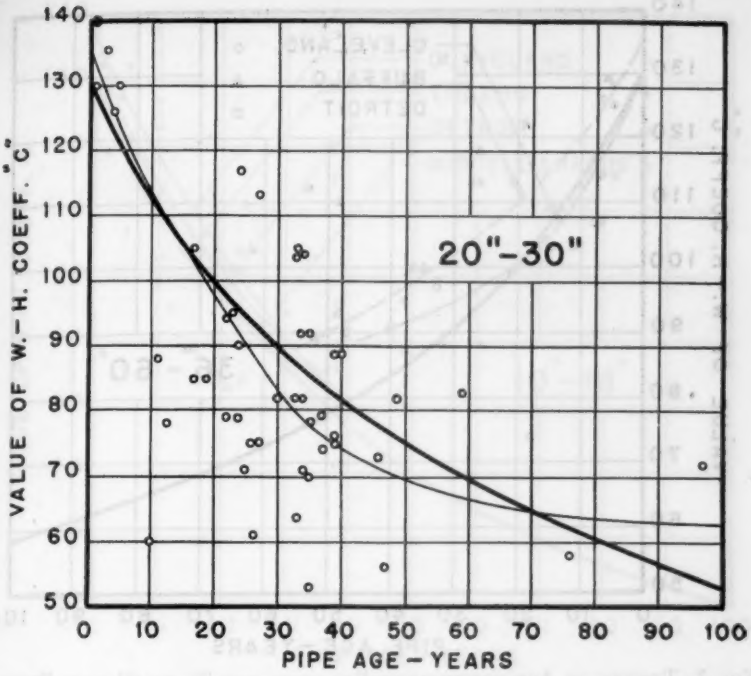

FIG. 5. TRENDS OF AGE-COEFFICIENT RELATION FOR 20- TO 30-INCH PIPES—PHILADELPHIA

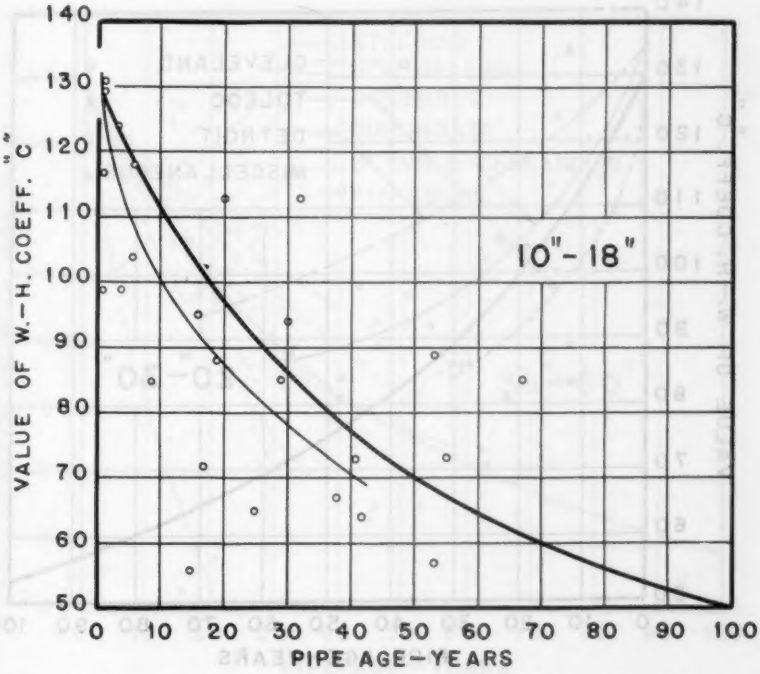

FIG. 6. TRENDS OF AGE-COEFFICIENT RELATION FOR 10- TO 18-INCH PIPES—PHILADELPHIA

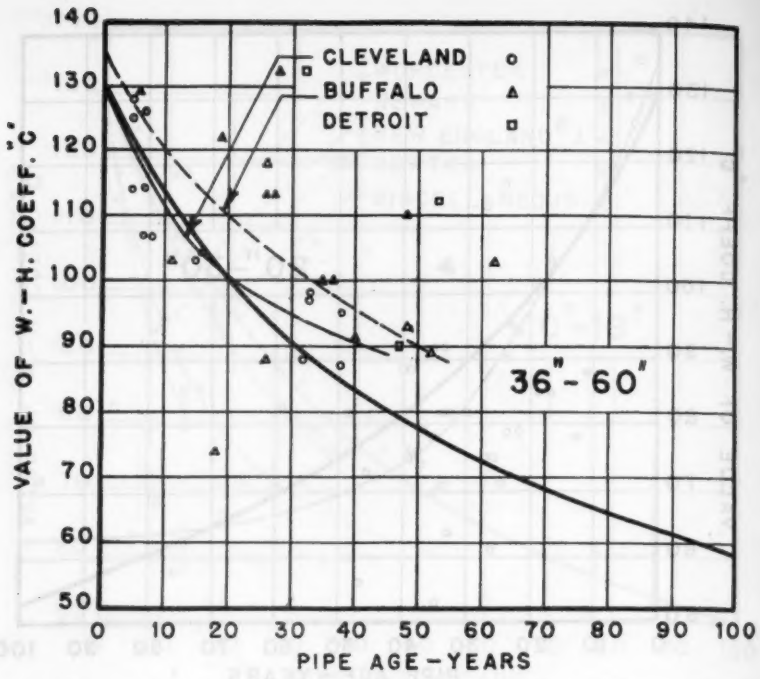

FIG. 7. TRENDS OF AGE-COEFFICIENT RELATION FOR 36- TO 60-INCH PIPES—GREAT LAKES BASIN

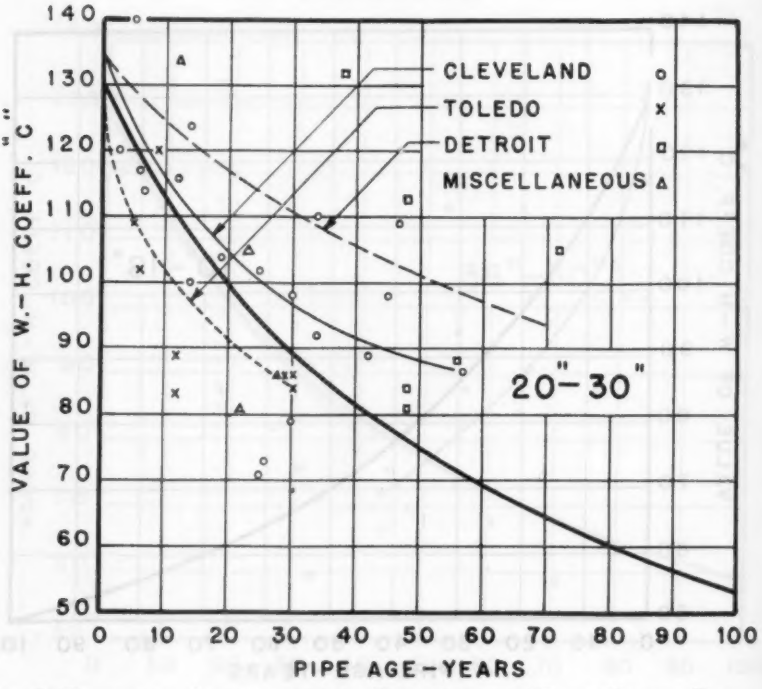

FIG. 8. TRENDS OF AGE-COEFFICIENT RELATION FOR 20- TO 30-INCH PIPES—GREAT LAKES BASIN

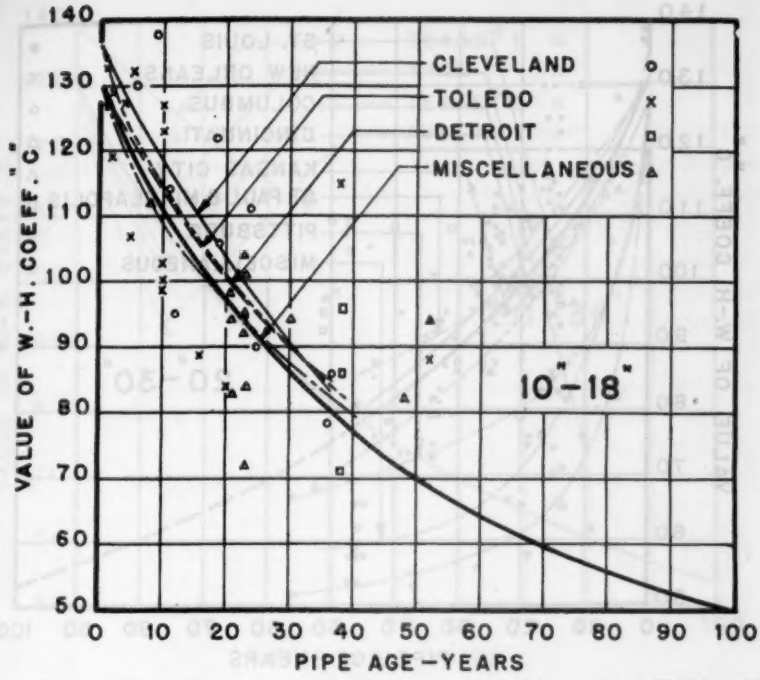

FIG. 9. TRENDS OF AGE-COEFFICIENT RELATION FOR 10- TO 18-INCH PIPES—GREAT LAKES BASIN

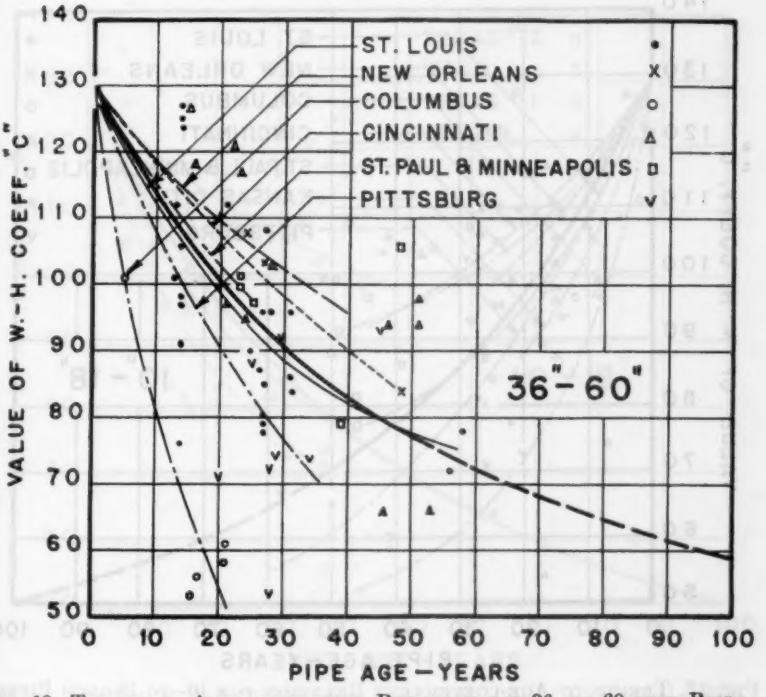

FIG. 10. TRENDS OF AGE-COEFFICIENT RELATION FOR 36- TO 60-INCH PIPES—MISSISSIPPI RIVER

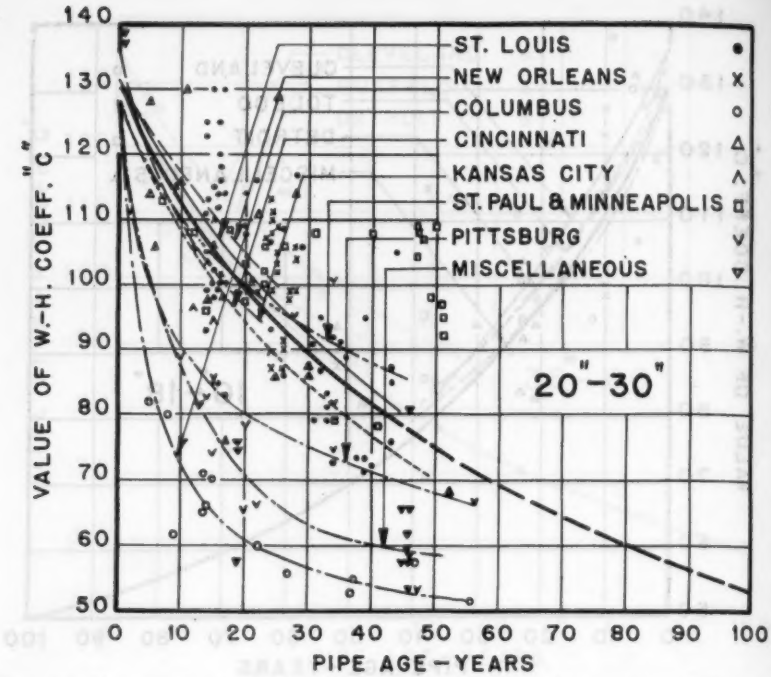

FIG. 11. TRENDS OF AGE-COEFFICIENT RELATION FOR 20- TO 30-INCH PIPES—MISSISSIPPI RIVER

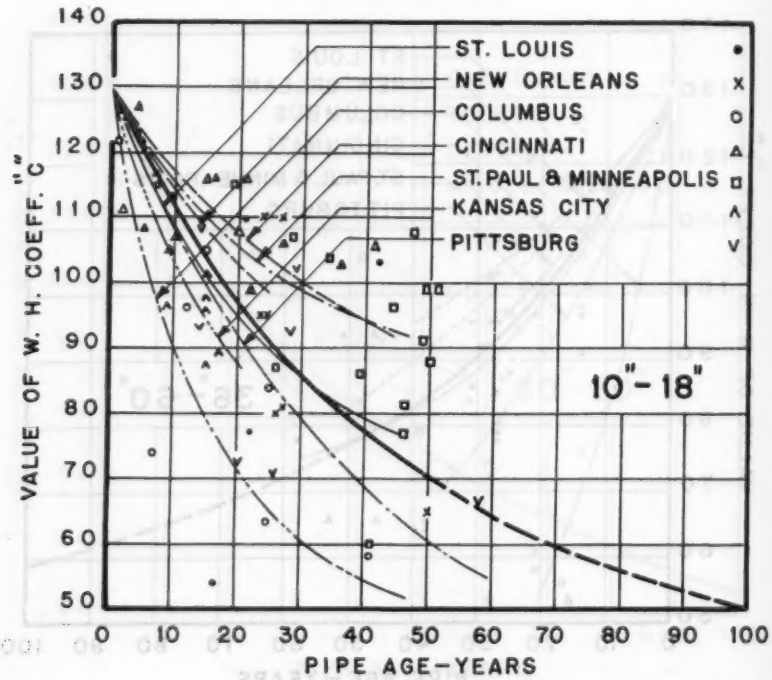

FIG. 12. TRENDS OF AGE-COEFFICIENT RELATION FOR 10- TO 18-INCH PIPES—MISSISSIPPI RIVER

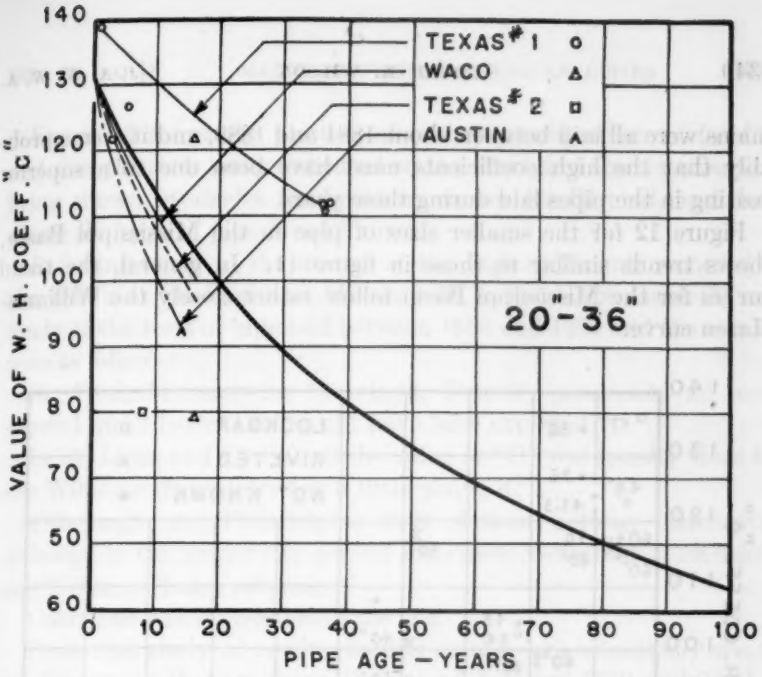

FIG. 13. TRENDS OF AGE-COEFFICIENT RELATION FOR 20- TO 36-INCH PIPES—TEXAS

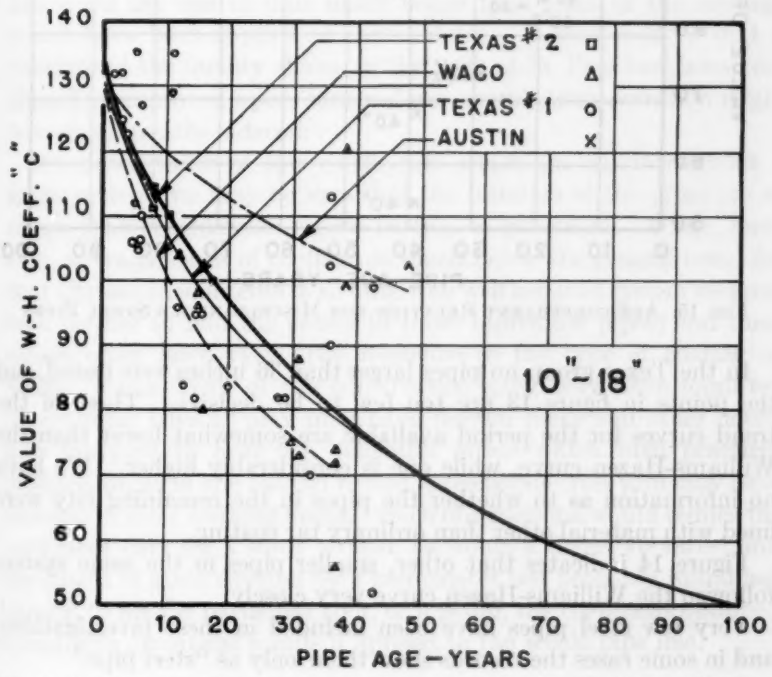

FIG. 14. TRENDS OF AGE-COEFFICIENT RELATION FOR 10- TO 18-INCH PIPES—TEXAS

mains were all laid between about 1884 and 1889, and it seems probably that the high coefficients must have been due to a superior coating in the pipes laid during these years.

Figure 12 for the smaller sizes of pipe in the Mississippi Basin, shows trends similar to those in figure 11. In general, the trend curves for the Mississippi Basin follow rather closely the Williams-Hazen curve.

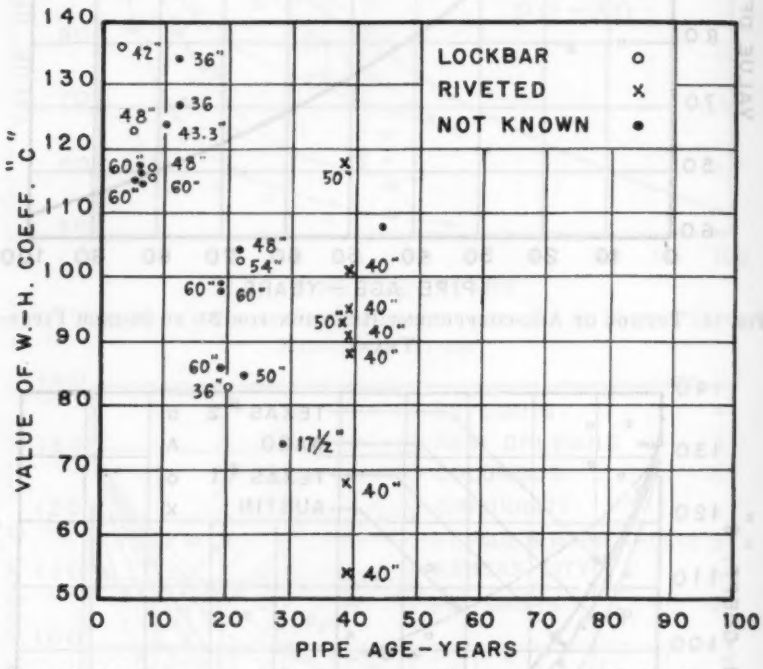

FIG. 15. AGE-COEFFICIENT RELATION FOR MISCELLANEOUS STEEL PIPES

In the Texas group no pipes larger than 36 inches were tested, and the points in figure 13 are too few to be decisive. Three of the trend curves for the period available are somewhat lower than the Williams-Hazen curve, while one is considerably higher. We have no information as to whether the pipes in the remaining city were lined with material other than ordinary tar coating.

Figure 14 indicates that other, smaller pipes in the same system followed the Williams-Hazen curve very closely.

Very few steel pipes have been included in these investigations, and in some cases the records show them only as "steel pipe."

Figure 15 shows the plotting of such pipes regardless of locality and size, the sizes being indicated on the chart and the classification being shown by circles for Lockbar, crosses for Riveted, and dots where the type of pipe is not known.

Referring again to the matter of the high coefficients recorded in the 1880's at St. Paul and Minneapolis, a tabulation, table 5, was made of the tests of pipe laid between 1880 and 1890 and the results were as follows:

St. Paul, Minneapolis, Cleveland, Detroit—practically all tests showed much better than might have been expected;

In St. Louis and Cincinnati the value of "C" was usually close to the Williams-Hazen curve or a little above it;

Pittsburgh and Philadelphia tests showed nothing conclusive, although in the former city several tests gave coefficients much below the Williams-Hazen criterion;

Columbus was entirely below the line.

From this study of results, limited as the data admittedly are, it would appear that at about the period between 1880 and 1890 a tar coating was being applied, at least by some manufacturers, which has stood the test of time much better than some of the coatings which have been applied at earlier dates. It may well be that if coatings of the quality shown in the tests at St. Paul had been continued or improved upon, much of our trouble with corrosion might have been greatly reduced.

When we think of low coefficients which prevail throughout a given system, we may be sure that the interiors of the pipes are so rough that considerable excess friction is generated. When, however, sporadic cases of coefficients much below the general trend for that city are encountered in an otherwise well behaved system we must look further to find the causes in those individual pipes; and these causes often have very little reference to the type of coating or lining. Some Tony of the construction gang may have forgotten his overalls, boys at play may have thrown rocks and other debris into the pipe to hear the delightful noises which such practices produce, or, as in one case on record, a telephone cross arm may have sneaked in after working hours. Such obstructions would reduce the coefficient only for a short section, as would a defective valve; and the length of main covered by a manometer test probably would not happen to hit the particular spot, or if it did, the coefficient obtained would give erroneous results if applied to the whole pipe line.

A considerably more important local obstruction which is usually overlooked in the discussion of pipe coefficients is one which has nothing to do with the interior condition of pipes yet plays a major part in the passage of water through the pipe. A pipe may be as smooth as glass on the interior surface, and yet if there is an opportunity for an air pocket to form the effect is the same as if the pipe were badly corroded. In one such instance where the 36-inch pipe had a coefficient of only 15, the pipe was unwatered and entered. About three hundred feet from the reservoir end a section of the pipe covering the greater part of its circumference was found to be only damp, showing that no water had been directly in contact with it. At this point an air valve was inserted and after the pipe had been filled and the air blown out, the coefficient was determined as 116. Other similar instances which have come under the author's observation indicate the necessity of careful examination to determine whether there is possibility that a pipe may be air-bound, when a low value is found for its coefficient.

The tests of pipes lined with other than the ordinary coating which have come under the author's direction have been too few to pass any judgment on their merits. A partial list of these follows:

LOCATION	SIZE, INCHES	AGE, YEARS	COEFFICIENT "C"	MATERIAL
A Maryland city	36	9	146	Concrete
New England No. 1	12	25+	136	Cement
New England No. 2	14	25+	126	Cement
A Pennsylvania town	12	1	134	Cement lined cast iron
A Pennsylvania town	11.44	1	148	Cement lined cast iron
A Pennsylvania town	11.31	1	159	Talbot lining
Passaic, N. J.	14	2	145	Transite pipe

The title of this paper includes a discussion of the effect of various waters on the coefficient of pipes. This is a matter somewhat outside of the experience of the author, but analyses of water have been obtained from a number of the plants where investigations have been made. Such data as have been made available are presented in connection with the tables containing the details of the tests presented herewith.

CONCLUSIONS

1. From the results of tests shown in the charts presented herewith, the conclusions of the committee of the New England Water

Works Association are apparently in general justified as regards the trends in various sections of the country. Their claims, however, should be used with caution and individual rather than average trend curves should be consulted.

2. There is a somewhat apparent basis for the opinion that pipe linings used in the 1880's have preserved the carrying capacities of pipes to a greater extent than those in use at later dates. While sufficient data are not available at present to prove this definitely, in several instances definite indications are found of such a tendency.

3. Air pockets in the mains are a source of greater obstruction than may be generally realized. Even though the interior of the pipe is in good condition the resulting loss of head will produce a very low coefficient, usually quite out of line with those prevailing throughout the rest of the system. This is especially apt to occur in trunk mains, or other pipes from which there are no service or hydrant connections, unless high points in the line are vented. It has been found that even a peak not greater than the diameter of the pipe may cause a serious obstruction.

4. Charts are presented showing the results of loss of head tests in numerous cities in various parts of the country, and tables which show the details of these tests. The trend curve from the Williams-Hazen Tables is shown on each chart, which trend curves for the individual cities, wherever sufficient tests have been made to justify such curves.

In conclusion, the author wishes to express his appreciation of the courtesy of the water works officials who have so kindly and generously allowed the use of the data of surveys made in their cities.

ECONOMIC SIGNIFICANCE OF IMPROVED PIPE LININGS

By F. A. Barbour

(Consulting Engineer, Boston, Mass.)

The results of the investigation of the relation between capacity and age of tar-dipped cast iron pipe by a Committee of the New England Water Works Association are of immediate practical interest to waterworks men.

The objective of this brief paper is to call attention to the significance of these results, simply and without detailed technical discussion, and to point to the importance of the further investigation of pipe line friction loss to be carried on jointly by the New England Water Works Committee and a Committee of the A. W. W. A. newly appointed.

It has been more or less customary in designing pipe systems to determine the diameter of tar-dipped pipe, necessary for an estimated future capacity and allowable friction loss, on an assumed value of the coefficient C of 100, or that which in the Williams and Hazen tables is estimated as probably resulting fifteen or twenty years after installation in pipes ranging from 6 to 60 inches in diameter. Assuming an average coefficient C of 130 for the pipe new, this assumption of a future coefficient of 100 means that pipe systems have quite generally been designed on an anticipated loss in capacity of approximately thirty percent.

The results of 473 tests of friction loss of pipes averaging 20.5 inches in diameter, investigated by the Committee, show at an age of 20 years an average coefficient C of 73, or a capacity loss of 44 percent, and at an age of 30 years an average C of 63 or a capacity loss of 52 percent.

Grouped in relation to diameter the tests also show for tar-dipped pipes 16 inches and larger, that the average coefficient at 20 years falls to 93 and at 30 years to 85 while in the small size, ranging from 4 to 12 inches in diameter, the average coefficient in 20 years falls to 55 and in 30 years to 45—equivalent to capacity losses respectively of 56 and 64 percent, or—again respectively—doubled and 1.6 times

the losses estimated for 8-inch pipe at 20 and 30 years in the Williams and Hazen hydraulic tables Also, it is to be noted that tar-dipped pipe lose capacity in the early years of use relatively much more rapidly than has been generally estimated.

The tests reported by the Committee, therefore, show that instead of the 30 percent capacity loss which has been commonly assumed to result at some more or less indefinite future date, substantially greater losses—in the smaller sizes running up to double 30 percent must be recognized.

In the light of these results the question may well be asked as to whether there is any economic justification for the continued use of tar-dipped pipe.

The investment value of a cast iron pipe is measured by the hydraulic usefulness of the pipe, and not by its life as a metallic structure. In the average waterworks the cast iron pipe lines probably account for more than 75 percent of the total cost of the physical plant, and at the present time, more than 85 percent of the tonnage of cast iron pipe sold for waterworks purposes is tar-dip coated. Is there any rational explanation of the continued acceptance of a coating which permits such rapid loss in value of so large a part of the total investment in waterworks systems, as is indicated by the report of the Committee?

Economically, at least, the answer depends on the relative maintenance of future capacity by a tar-dipped coating and by the centrifugally applied cement and bitumastic linings now obtainable.

Unfortunately the maximum age of the centrifugal linings tested and reported on by the Committee are limited to six years in the case of cement and to two years in the case of bitumastic. At these ages no reduction in the initially high coefficients was found. A test of a 16-inch pipe—cement lined but not by the centrifugal process—showed a coefficient of 131 at an age of 10 years and tests of 12-inch and 14-inch wrought iron pipes, cement-lined by the mandrel process, showed a coefficient of 103 at 41 years. Cement lined services in Worcester, Massachusetts, are in good condition at the end of 60 years of use. Additional data as to the continued capacity of cement lined and concrete pipe and of bitumastic lined pipe are clearly needed, but from present information it would seem reasonably safe to conclude that a sustained coefficient of 100 for sizes 12 inches in diameter and smaller and of 120 for larger sizes may be estimated.

At the present time, the costs of cement lining—as adopted by the manufacturers—range from 4 cents per foot for 4-inch pipe to 90 cents per foot for 48-inch pipe, and for bitumastic coating from 7 cents per foot for 4-inch pipe to $1.80 per foot for 48-inch pipe.

On the basis of these charges cement lining—depending on the diameter of pipe and local conditions—adds from 3.0 to 5.0 percent to the total cost of a pipe line, where no paving is cut or replaced, and roughly two-thirds of these percentages where paving is a factor in the work. Similarly, bitumastic coating adds 5.0 to 8.0 percent to the total cost, without allowance for paving.

But, crediting the improved linings with a sustained value of C of 120 in the larger sizes—a possible reduction in the diameter of the pipe for the same future capacity will make possible a saving in first cost over that of a tar-dipped pipe for the same future capacity, wherever the future coefficient of the tar coated main may be expected to fall below a value of C of 100. Similarly, in the smaller pipe sizes a sustained coefficient of C of 100 for the improved coating will make possible a saving in first cost when the future coefficient for a tar-dipped pipe may be expected to fall below a value of 80. Since the coefficients shown by the New England Water Works Association Committee to actually occur are substantially less than 100 in the larger sizes and 80 in the smaller sizes, a material saving in first cost is clearly possible by reduction in the necessary diameter of the pipe laid with the improved linings. Thus, to illustrate—assuming that a 30-inch tar-dipped main with C of 75 at an age of 30 years is necessary to provide at that date for an estimated required capacity and allowable loss of head—an improved coated main with a sustained value of C of 120 requires for the same future capacity and allowable loss of head a diameter of 25.1 inches, or, in terms of commerical sizes, 70 percent of the length of the line can be reduced from 30-inch to 24-inch diameter, and a saving in total first cost of approximately 15 percent effected.

Obviously, where such a saving in first cost is possible no dollars and cents argument remains for the tar-dipped pipe, and the econoics of cleaning, relining or recovery of lost capacity by group reinforcement cannot enter the problem.

It is, of course, to be recognized that the possibility of reducing the diameter by the use of coatings guaranteeing higher sustained hydraulic values is limited to transmission and feeder mains, designed to provide for some estimated future capacity, but in the smaller

sizes of the gridiron system, where diameters are fixed by certain adopted minimums based on fire service requirements of immediate importance, the economic argument for coatings which will maintain capacity still remains. Here it is true that a smaller commercial size may not be possible and thus an initial greater cost, varying from 3 to 5 percent for cement lining and 5 to 8 percent for bitumastic lining may be necessary. Here, however, the value of the sustained fire service capacity, the discounting of the necessity of replacement or reinforcement with consequent interruption of service and traffic, all clearly point to the use of a better coating than the tar-dip, which in the smaller sizes is shown by the Committee to lose in 30 years three quarters of its initial capacity.

What then is the reason for the present acceptance of 85 percent of the total tonnage of cast iron pipe with a tar-dipped coating at least not better than that tested by the Committee? Does such acceptance constitute an indictment of those responsible for the selection of this major investment item, or is it justified by doubts as to the success of the improved coatings now obtainable, or by other reasons than cost? If the latter, then a profitable field for further research is indicated.

The report of the New England Water Works Association Committee is in any case a clear call to the manufacturers of cast iron pipe to provide, and to the members of this Association to use, a pipe lining which will guarantee better sustained hydraulic capacity than is provided by the present tar dip.

THE REHABILITATION OF LARGE WATER MAINS IN NEWARK, NEW JERSEY

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The City of Newark, New Jersey, early in 1934 adopted a program of work required to correct deficiencies both existing and imminent in carrying capacities in its aqueduct system conveying water from the Pequannock Watershed to the City. This work program, involving a total of 50 miles of 32 to 46 year old riveted steel pipe-lines ranging in size from 36 to 60 inches in diameter, has as its ultimate aim, first, to restore capacity lost through excessive tuberculation and to insure additional years of service and, second, to provide an alternate route to convey water from the main distributing reservoir at Cedar Grove to the distribution system. It is to be accomplished over a period of five years by a step-by-step procedure of reconditioning and replacement of existing pipe-lines and the addition of a comparatively short section of new pipe connecting portions of the Pequannock Aqueduct system.

The major portion of this proposed work, approximately 75 percent of the total length involved, consists of reconditioning the pipe lines by cleaning the interior surfaces of the pipes and applying a protective lining. It is believed this will not only restore the original capacity, but will protect the steel surfaces and prevent the recurrence of capacity loss. Some sections of the pipe lines are scheduled for replacement. These are in locations where examination of the outside plate by means of test pits dug at frequent intervals, showed that exterior corrosion had advanced to a stage where cleaning and lining were considered unwarranted.

ORIGINAL AQUEDUCTS

The reconditioning program is possible because of the fact that two parallel lines extend for the entire distance from the collecting reservoirs to the large distributing reservoir at Cedar Grove. It is

apparent that considerable care was taken in providing a protective lining on the interior of the pipes when they were laid. A selected bituminous material was applied by dipping. Each pipe was twice dipped in this heated bitumen. Where an appreciable thickness of lining occurred it is still in place and is still offering complete protection to the steel surfaces beneath. Elsewhere tuberculation has occurred with pittings under tubercles extending to a depth of 0.125 inch, the largest pittings having a diameter of about an inch and a half. The extent of tuberculation of the lines is indicted by a reduction of carrying capacity to about 70 percent of their original capacity. Nowhere has interior corrosion weakened the pipe appreciably. The loss in strength is estimated as nowhere more than 5 percent. In places rather serious exterior corrosion has taken place. This has occurred in locations subject to special conditions, in general of an electrolysis nature. At such points perforations develop from the outside and leaks occur, sometimes frequently. One particularly bad stretch of 36-inch steel line 2700 feet in length through wet clayey soil in one of Newark's Parks has been replaced. Other short sections of this time same pipe are in bad condition and scheduled for replacement. Not until the reconditioning work has advanced considerably will we have even an approximate idea of the amount to be replaced. In the program of aqueduct reconditioning the sections of pipe scheduled for replacement totalled 40,000 feet. With reconditioning work costing about one-fifth of the cost of replacement, it is evident that the replacements will be held down to the least possible amounts.

CHARACTERISTICS OF NEWARK WATER

The water of the Pequannock Supply is slightly aggressive, being a surface water, soft in character, unfiltered and purified by sedimentation. For many years when the aqueduct was first placed in service no chlorination was used. Chlorine treatment began in 1923 and since 1932 ammonia has also been applied as required for effective chloramine treatment. Average chemical characteristics of the water are: pH Value 7.0; free carbon dioxide 1.0 to 3.0 p.p.m.; dissolved oxygen 9.0 p.p.m.; bicarbonate value 24.4 p.p.m.; total solids 53.8 p.p.m.; ignition loss 21.8 p.p.m.; iron content 0.2 p.p.m.; calcium 9.0 p.p.m.; sulphates 10.7 p.p.m.; and color 23. From the beginning, water of the above type has been fed through the Pequannock steel aqueduct. Heavy runoffs in the watershed have altered the above amounts at times, causing both increase in silt and in organic matter in solution and suspension.

Chemical examination of the tubercles formed on the interior pipe walls, made to note their character of composition, showed that 78.25 percent of the tubercles were oxides of iron and aluminum; 13.8 percent represented loss on ignition; silica 5.0 percent; sulphates 1.34 percent and less than 0.5 percent calcium. Profuse bacterial growths were found when the internal structures of the tubercles were examined bacteriologically. The bacteria were anaerobic in character and were of the proteolytic type.

RECONDITIONING WITH BITUMINOUS ENAMEL LINING

The first reconditioning work undertaken by the City of Newark consisted of cleaning the tuberculated interior of 40-year old, 42-inch diameter riveted steel pipe, made up in 7½ foot courses, and recoating with bituminous enamel applied hot over a priming solution applied cold to the carefully cleaned and dried surfaces. The work was started in the vicinity of the Belleville Distributing Reservoir in November, 1933, as a Civil Works Administration Project and was carried on as such, until April, 1934, when C.W.A. aid terminated. Difficulties were encountered towards the end of the work, with moisture on the steel surfaces in the line, caused by differences in temperature between the warm outside air and the pipe metal. It was necessary to put the line back in service for high rates of draft due to warm-weather consumption. The line continued in service until the reconditioning work was resumed in October, 1935, as a Works Progress Administration Project. At this writing the work is still in progress with difficulties due to condensation of moisture on the pipe walls, apparently under control.

The line, which incidentally is not the oldest steel pipe in the Newark system, was laid with manholes 800 to 1000 feet apart and with 1¼-inch pass-holes, through which the hot rivets were passed during construction, in the top of the pipe at 30-foot intervals. The man-holes and pass-holes were uncovered and opened, no other part of the pipe being uncovered.

During operations in a section, it is lighted by electric lights 12 to 15 feet apart, supported on struts in the pipe, and is ventilated by suction fans located at manholes. Both the lights and fans are operated by current furnished by the local utility company, which established transformer connections from which it furnishes current through meters. The lamps are protected by wire guards and, in addition, each painter, when applying the enamel is provided with a hand light which he holds in one hand while painting with the other.

In ventilating a section, a bulkhead is placed just beyond each of the two manholes which limit the section, and a fan is located above one of these manholes. As it is necessary to use the manholes for the passage of men and materials, while work is in progress, the fan cannot be set directly in or on it, but an "air lock" is used—a small, square frame shed set over the manhole and made air-tight, in the roof of which is set the exhaust fan with a vertical shaft carrying its motor on top, enclosed in a weather casing. The door of this "air lock" is opened as seldom and briefly as possible, a door man being in charge. The fans are of 3500 cubic feet capacity and give a velocity of air through the pipe of 3 feet per second. As the air in the pipe is used by a great number of men, ventilation is necessary to carry off the dust caused by the scraping and brushing and the fumes from the paint. All men, when scraping, wear goggles and dust-proof respirators, while the painters wear goggles and chemical respirators.

For removing the tubercles the men use two-handed scrapers, which are flattened at the end to an edge about 2 inches wide, and regularly sharpened. The material scraped off, together with the bottom deposits, is placed in burlap bags and removed at the nearest manhole. Following this, the surface is brushed with motor-driven wire cup brushes, a ball of steel shavings being placed in the cup to increase the area polished. Finally, just before the surface is painted it is wiped off with rags, purchased in bales and found cheaper and better than waste.

In recoating the pipe, it is first painted with the priming solution applied cold with wall brushes. When this is dry, usually the following day, the bituminous enamel, heated in tar kettles to 425 degrees, is applied, using Tampico fiber daubers. The dauber is dipped in the hot enamel and applied to the pipe surface with a 9-inch stroke, forward and back. It is again dipped and applied, each stroke overlapping the previous one, care being taken, using the hand light, to see that all the surface is covered to a thickness of $\frac{1}{8}$-inch. An instructor to train the men in applying the coating was furnished by the manufacturer of the bituminous materials who also supplied heating kettles. Extreme care is used to insure the hot enamel being kept at the proper temperature. The enamel buckets are replenished through funnels at the nearest pass-holes. A simple signal system is used to notify the kettle man that the painter below needs more material. Tar kettles are cleaned at the end of each day to remove the accumulation of coked material which tends to form.

When the coating in a section between manholes has been com-

pleted, the entire surface is inspected by a city representative and, when acceptable, the section is isolated to prevent damage to the finished lining.

The primer and enamel, together with all of the skilled and unskilled labor, including foremen and general supervision, have been furnished by the C.W.A. and W.P.A. The city furnished all of the electrical equipment required, as well as boots, gloves, goggles, brushes, tools, etc.; also inspectors and an engineer in charge. Approximately 150 men have been used on the work most of the time while it has been in progress.

From the start of the work in 1933 to date of this writing, about 8000 lineal feet of 42-inch pipe have been completely and satisfactorily reconditioned.

Much thought has been given to procedure to enable the reconditioning work to continue as the warm weather of summer approaches and moisture collects on the cold steel surfaces of the underground pipe. Air is now drawn into the pipe through charcoal and ground cork filters located at an opening in the pipe at a considerable distance from the location where enamelling is under way and in the portion of the pipe which has been already enamelled. The charcoal and cork, which is removed and dried twice daily, takes some moisture from the air entering the pipe. The entering air is cooled to the temperature of the underground pipe as it passes through the section already enamelled and the condensation forms on the enamelled surfaces. By the time it reaches the section where men are working the air has dropped its excess moisture and a dry pipe results. It remains to be seen whether or not this will be the case during hot muggy days.

RECONDITIONING WITH CEMENT-MORTAR LINING

Work done under contract on the second section scheduled to be reconditioned was started in November, 1935 and completed in May, 1936. This work consisted of cleaning 27,500 lineal feet of 40-year old, 48-inch diameter riveted steel pipe, made up in $7\frac{1}{2}$ foot courses and relining with a protective coating of cement-mortar with a thickness of $\frac{1}{4}$-inch. This section of line, one of the Twin Pequannock conduits, extending from Macopin Intake to Pompton Notch, is located in the highland area of New Jersey and runs through a rugged and hilly country. Grades as steep as 33 percent occurred with ten

percent of the line on grades steeper than 12 percent. The undulation of the vertical alignment increases the length of line, measured along the axis about 1000 feet in 27,400 feet horizontal measurement.

FEATURES OF SPECIFICATIONS

The purpose of the exacting requirements of the contract specifications under which this work was done, was to insure a lining which, for many years, would protect the steel surfaces of the interior of the pipe to which it is applied, would cover the surfaces completely and remain in contact firmly with the same notwithstanding the expansion and contraction of the pipe due to filling and emptying the line, to variations in pressure and to temperature changes. Recent inspections show that there is every reason to believe that this has been attained. A maintenance bond guaranteeing this desired result was furnished by the Contractor covering a period of two years, in addition to the regular construction and material and labor bonds.

Provisions in the specifications gave the City the right to order all or any part of the work suspended, without any claim on the part of the Contractor, in order to place the line in service to replenish the storage in Cedar Grove Reservoir. It was necessary to take advantage of this stipulation during the past winter when the work was suspended for a period of five weeks in order to refill the depleted storage reservoir due to the lack of carrying capacity of the other twin line during an unexpected peak of cold-weather consumption. No more definite proof could have been provided of the truth of the Engineer's contentions that this reconditioning work could not be long delayed.

It was anticipated that sections of the line through swamps, stream beds and elsewhere would be pitted on the outside to such an extent that, with the inside pitting, a considerable weakening of the pipe structure would result. Provision was made for linings of various thicknesses greater than $\frac{1}{4}$-inch in order to reinforce the steel pipe and offer resistance to the loss of water from the line in the future as outside pittings perforated the steel shell. The lining applied to several sections of the pipe was increased to a $\frac{5}{8}$-inch thickness after the need thereof was determined in advance by a careful examination of the exterior by means of test pits and the interior subsequent to the cleaning operations. Two short sections, one located under a stream bed and the other under a road crossing, were lined with a 1-inch thickness.

PREPARATION OF THE LINE

In preparation for the work of cleaning and relining by contract, the City uncovered and opened all entrance manholes in the section of steel pipe to be relined of which there were 24, spaced about 1000 feet apart; unwatered the lines; provided openings in the steel pipe line for the insertion and withdrawal of equipment, at four points; placed bulkheads to prevent any possibility of water in volume entering the section in which men were working; repaired by welding about 10 perforations or deep pittings in the steel pipe walls before the new

FIG. 1. LARGE MACHINE LEAVING PIPE AFTER CLEANING OPERATION

lining was applied; replaced and recovered all entrance manholes and the pipe sections at the four openings after the Contractor has completed the work; and refilled the line, sterilized it and restored service through it.

The openings provided for the access of mechanical cleaning equipment were made by the removal of an 8-foot section of the pipe which later was replaced and connected with Dresser Couplings. This method provided a section which could be readily removed and replaced as required. The section was taken out intact by making

two circumferential cuts on a slight batter with acetylene torches. The four ends, two on the removed section and two on the pipe in place in the ground, were adapted to the couplings by forming a welded butt joint to fit a 48½-inch coupling.

CLEANING OF THE LINE

The cleaning of water mains has become familiar to most water works operators, either from their personal observations and experience or from descriptive articles which have appeared from time time to time in the several Society Journals and water works publications. In general, the work of cleaning large mains offers no great difficulty providing water under pressure is available and there

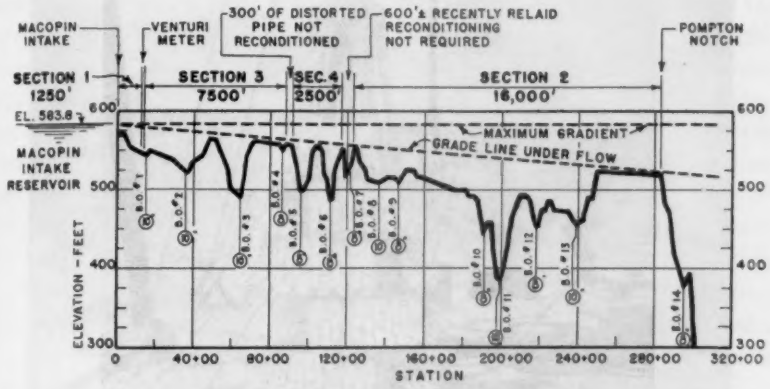

FIG. 2. CLEANING AND RELINING SECTIONS OF PEQUANNOCK PIPE LINES

are adequate facilities for carrying off flushing water and the debris removed during the cleaning operations. In ordinary cleaning, after a long run, the cleaning machine may be expected to emerge much as shown in figure 1.

The cleaning of the 48-inch riveted steel No. 2 Pequannock pipe line which was to be cement lined presented some unusual difficulties; first—because the line is telescoped and lap-joint riveted steel constructed in seven foot courses; second—because, in many places, it was considerably out of round and finally—because it is laid so close to the hydraulic gradient that pressure, especially at the beginning of the line, is hardly adequate to operate the cleaning machines.

The first section laid out to be cleaned was about thirteen hundred

feet long, extending from the intake well in the gate house at Macopin Reservoir to the Venturi meter. Within a few feet of the gate house there is a 22½° short-radius cast-iron bend and from there on the steel pipe follows a wide curve. No opening was to be made at the end of the first run so that the original plan was made and equipment designed to use a cleaner which, after its passage through the line,

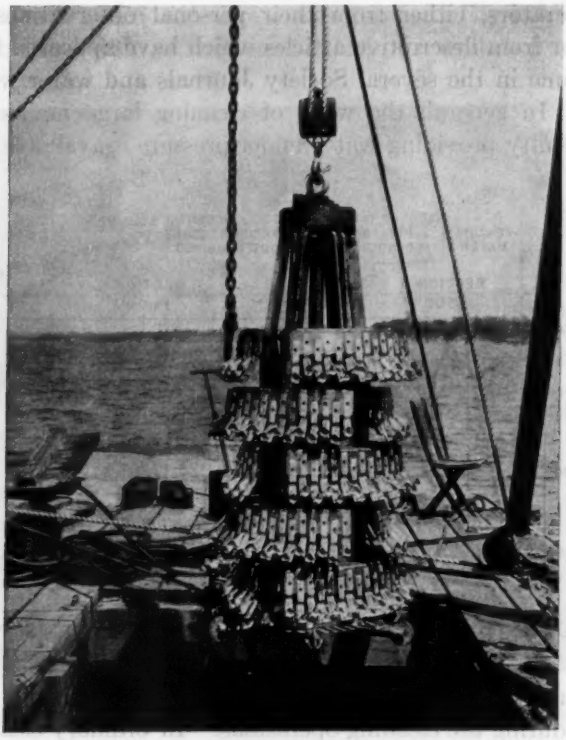

FIG. 3. COLLAPSIBLE MACHINE

could be reduced in diameter and pulled back for removal at the intake well. This collapsible type of machine is shown in figure 3.

The handling of the machine in the limited space of the gate house and well offered some problems but it was finally entered into the pipe line through a funnel by means of jacks. At first a windlass and cable were used in an attempt to pull the machine but, because of the curving layout of the pipe line, there was too much friction of the cable along the side of the pipe to utilize the full work of the

windlass and pulling alone would not operate the machine. Then water pressure alone was tried. The ordinary head of thirteen feet at the gate house was not enough to start the device nor was it possible to move it beyond the bend with the twenty feet of head obtained by closing both inlet and outlet valves in the well and filling the well to the gate house floor by means of a centrifugal pump. While the machine moved forward under a twenty foot head it only reached the cast-iron bend about twenty feet from the entrance. The machine

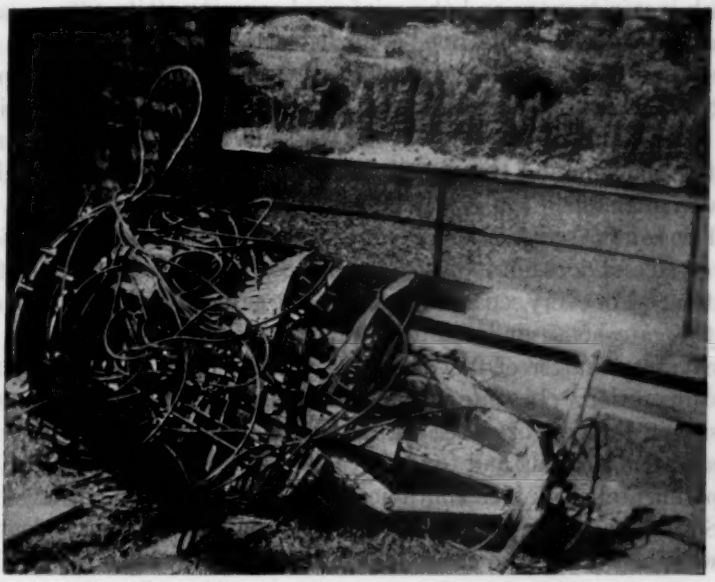

FIG. 4. THE WRECKED MACHINE

was then jacked around this bend with the hydraulic jack and long timbers. The same method of building up the head was again used, but, due to the friction of joints and rivets in the pipe, this water pressure was inadequate to start the machine. Therefore, a cable was brought up through the line from the Venturi and attached to the front of the machine. It required both the windlass and cable plus the water pressure to start the machine but, unfortunately, once the machine was under way it over-ran the cable, became tangled on it and was badly wrecked. It traveled, however, to the bulk-head, erected in the line to protect the Venturi meter from damage, and

then, with much difficulty, it was pulled back to the gate house and removed. Upon its removal it appeared as shown in figure 4.

Due to the wrecking of the machine the pipe had been only partially cleaned and another type of machine was entered into the line at the gate house and traveled through with good results under water pressure alone, after providing an air inflated piston described below. This machine was designed and specially constructed so that it could be dismantled with a minimum of difficulty inside the pipe line and removed piece by piece. The ordinary type of piston allowed so much water to pass and the reinforced scraping units were so stiff that the machine could not be started with the available head. A special air inflated piston was then built, the tension on the scrapers reduced and the machine successfully shot through the first section. At the end of the run the mechanics worked both in front and in back of the machine and the dismantled pieces were removed through a nearby manhole.

This brief description gives only the "high-lights" of the operations involved and does not indicate the time consumed in cleaning the first section. For every separate operation the gate valves had to be closed in the gate house and the line drained before men could enter the line. As a matter of fact it took seventeen days to complete this first operation. In spite of this discouraging start, as there was no desire on the part of either the City or contractor to discontinue the mechanical cleaning and to clean the balance of the line by hand, the experimental work was continued.

So that the work of relining should not be delayed by the cleaning it was then decided to clean 16,000 feet at the lower end of the line from Station 122 + 00 to Pompton Notch. The collapsible machine was reconstructed and first used on this second section. This was a long run and the scraper has become worn and broken before its completion. A physical inspection showed that the pipe was about 75 percent cleaned. After repairs, this machine was again run through the line, emerging in good condition, and inspection showed a satisfactory cleaning job. This run was made without any unusual difficulties as the static pressure where this work was carried on was much better. The machine was run through a second time to insure a complete job of cleaning.

For the third operation the line was opened just beyond the Venturi down-stream at Station 13 + 18 and 7200 feet from the Venturi to approximately Station 87 + 80 were cleaned. The pressure at the

Venturi was enough to start the machine which was of the rigid type. The line ran up and down grade. At the low points in the line the blow-offs were opened and large quantities of dirt were washed out at these blow-offs but, even with this relief, the greater part of the removed incrustation had to be carried ahead of the machine to the end of the run. In every instance, after arrival at the low point in the line the blow-off valve was closed—then the debris, being heavier than the water, would begin to pile up ahead of the machine and frequently caused the complete stoppage of the machine on the up grades. When this happened it was necessary to go into the line ahead of the machine, after a shut-down and drainage and, with shovels, spread the incrustation for thirty or forty feet along the pipe ahead of the machine. Thus relieved and the water again turned on the machine would travel over the next high point.

The rate of travel could be readily followed as the noise of the eight hundred spring-steel scraping units passing over successive rivets sounded like the droning of a distant airplane. The gate-house valve was used to control the water and the rate of flow could only be changed gradually and after considerable time. The best results are to be expected when the machine travels slowly and continuously, but with the remote control in this line the rates of travel varied from 6 feet per minute with stops to allow pressure to build up when going up hill, to 258 feet per minute on the down grades.

The fourth and last section cleaned was about 2500 feet in length from Station 91 + 35 to 117 + 15. This was also cleaned with the rigid type machine.

Even with all the preliminary study made in connection with the cleaning work, unexpected difficulties would arise and it frequently required all of the resources of the Contractor's engineers and the City's engineers to overcome these obstacles.

In every run, means had to be devised to stop the cleaner in the pipe before it could reach the outlet cut. It was feared that if the machine were allowed to come out freely as in cast-iron pipe cleaning there would be a sudden drop in pressure which might cause a vacuum at some high point, resulting in collapse of the steel pipe. In order to stop the machine with least damage possible to it, bulkheads of 8 feet x 8 feet timbers were wedged in the line, then many sand bags laid up to serve as a cushion. For every pound per square inch pressure behind the machine there was about eighteen hundred pounds of actual pushing pressure, which is mentioned to give some idea of the force which had to be under control.

Much of the removed material was finely cut and ground by the machine and probably 60 percent of the total was carried off in suspension, leaving only about 40 percent to be shoveled out from ahead of the machine at the completion of a run.

Some hand cleaning was necessary after the mechanical work as, in places, the old bituminous lining firmly adhered to the pipe and had to be taken off with scrapers and wire brushes. Also, the small amount of rust and tubercles between rivet heads and in the deeper pittings had to be brushed out by hand.

The work took a great deal longer than was anticipated, but, in spite of the delays and the additional expense thus incurred, the cost per foot for this rough mechanical cleaning, plus the finishing hand work, was very much less than the cost of hand cleaning, which method had been used on previous work.

Sections of the pipe were carefully scraped, the areas measured and the incrustation weighed from which it is estimated that one hundred and five tons of incrustation were removed from the 28,000 feet of line cleaned in this manner.

CEMENT-MORTAR LINING EQUIPMENT

The equipment used in the application of the cement-mortar lining consisted of two groups, the mixing and power plants located on the ground level and the lining apparatus operating in the pipe; the first made up of two gasoline driven paddle-type mortar mixers, the necessary water and material storage facilities, and a portable gasoline-driven motor generator plant; and the second, all independently driven by electric motor through cable from power plant, included the centrifugal lining machine, a traveling screw conveyor equipped with a storage hopper, and a delivery car for transporting the material from the mixing plant to the lining equipment. Current was supplied by the power plant to the various units through cable wound on reels, figure 5.

The *delivery car* is an electrically driven pneumatic tired buggy, with steering facilities on both front and rear wheels and is equipped with a small hand operated hydraulic dumping rig. The body capacity is 7.0 cubic feet, each load being equivalent to 26 lineal feet of ¼-inch lining on a section of 48-inch diameter pipe. The delivery car requires one operator who receives the mortar at the access manhole and delivers and dumps it into the storage hopper of the conveyor.

The *conveyor* consists of a travelling hopper-type storage truck, equipped with an inclined screw feed and operates directly behind the main centrifugal unit of the lining machine. The travel speed of the storage truck is synchronized with the travel of the centrifugal lining machine. The truck is provided with pneumatic tires and is electrically driven by an independent variable speed motor for traction together with a slow speed shaft which drives the inclined screw, feeding mortar to the centrifugal machine. The hopper is of the same capacity as the delivery car, this storage providing ample time for the delivery car to make a round trip to the access manhole.

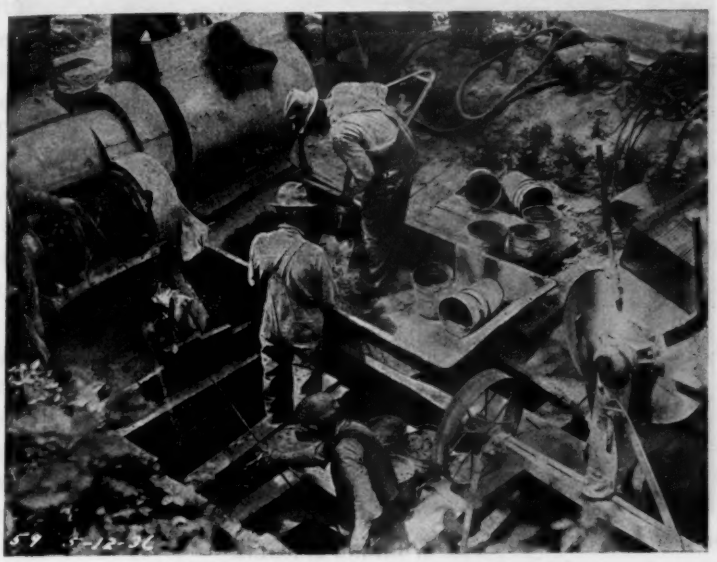

FIG. 5. MIXING AND POWER PLANT

The *lining machine* is a centrifugal device equipped with two electric motors, one for traction with a variable speed transmission, the other of constant speed which drives a short screw-feed conveyor, the mortar lining head and a set of a slowly revolving finishing trowels. A small hopper, of one cubic foot capacity, is mounted on the centrifugal unit and receives mortar from the conveyor previously described. A short slow-speed screw operating in this hopper forces the mortar at a constant rate from the small hopper directly to the center of the 6-inch cylindrical lining head, around the circumference

of which are rectangular or slotted ports. As the mortar passes through the ports it is thrown against the pipe wall by radially spaced high speed vanes which rotate outside of these fixed ports, at a speed of 1000 R.P.M. The actual lining head revolving at this high speed depends entirely on centrifugal force for placing the mortar. The high-speed shaft driving the lining head is hollow and in the interior is a slow-speed shaft turning at only 3 R.P.M., upon which are mounted four steel trowels which follow directly behind the lining head, two operating clock-wise and two counter clock-wise. The

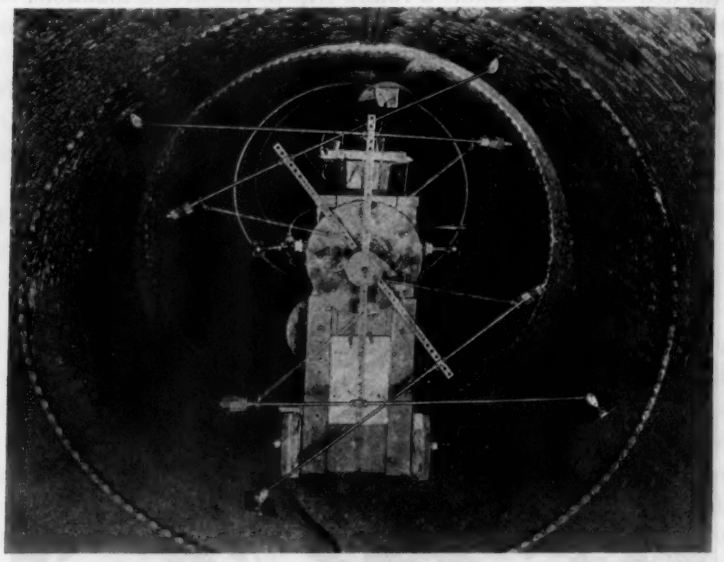

FIG. 6. LINING MACHINE

trowels are so designed and adjusted that their curved surfaces smooth and finish the lining after placing, figure 6.

The equipment as a whole is extremely flexible and provides a means of placing a lining of variable thickness. The travel speed of the lining machine can be so slowed down that thicknesses as great as may be desired can be obtained and so speeded up that thicknesses of any practical desired minimum, obtained.

APPLICATION OF CEMENT LINING

The lining application procedure for a days run was as follows:

The lining and conveying units were assembled in the pipe and

adjusted to start operations at the end of the previous days work and the mixing and power plants were set up at the next entrance manhole or access opening located at the end of the day's run, which arrangement permitted the lining operations to progress towards the mixing and conveying units. The mortar after being mixed for at least six minutes was chuted through the opening to the dump car, transported to the conveyor, loaded in the storage hopper of the centrifugal lining machine, and applied by the machine while the dump car returned to the mixer for another batch of mortar. After the lining operation had advanced to a point near the opening at the mixing plant which was at the end of the day's run, the working parts of the lining and conveyor units were removed, taken from the pipe and cleaned preparatory to the next day's work, the mixing and power plants moved and set up at the next opening and the procedure repeated.

The cement and sand after receiving special treatment at the contractor's plant were hauled to the work in bags of 85 pounds each. Water was obtained from the other twin pipe line, stored in barrels at the mixing plant and fed to the mixer with measuring pails. Perfect control of the water-cement ratio was easily maintained due to the fact that the moisture content of the sand was removed before the sand was bagged.

At points along this line where entrance manholes were spaced more than 600 feet apart, the contractor provided additional openings by removing a rectangular section of the steel plate 30 inches long by 24 inches wide. These plates were replaced by welding prior to the lining of the pipe at this point, so that the cement-mortar lining was continuous and unbroken past these locations.

To protect appurtenances, such as blow-off, air-valve and manhole connections, wooden plugs were inserted, so arranged as to be easily removed without damaging the lining after the machine had passed and the lining had set.

The specification, as applying to the curing of the lining required that immediately upon the completion of the lining of a section of pipe between manholes or of a day's run of the machine, the section of pipe shall be closed at either end, manhole openings covered and steam shall be introduced into the pipe between the bulkheads. The section of pipe shall be kept filled with steam until the mortar lining has set satisfactorily. In no event shall this period of steam curing be less than 48 hours. Bulkheads and manhole covers shall

be kept in position to prevent circulation of air and to keep the mortar lining moist until it has set completely in the judgment of the Engineer; and if necessary the cement-mortar surfaces shall be sprinkled.

At the end of about 4 hours from the time of completion of the lining, by which time the mortar had attained its initial set, steam was introduced into the section. Steam for curing was generated by small portable boilers using coke as fuel.

Bulkheads were made of a sheet of rubber cemented to a ring made to the diameter of the pipe from sections of rubber tire inner tubes vulcanized together to form one large tube. By inflating the tube the bulkhead could be made to fit tightly in the pipe. Thereafter it could be easily and quickly removed and replaced at will and carried from section to section.

The work was carried on in one 8-hour shift but at times overtime was required. A section between access openings, which averaged 500 feet in length, was the usual day's run irrespective of whether $\frac{1}{4}$-inch or $\frac{5}{8}$-inch lining was being placed. Under favorable conditions, two 500-foot sections of pipe could be lined, if the lining were $\frac{1}{4}$-inch. The maximum days run for $\frac{1}{4}$-inch lining was 1088 linear feet. The rates of progress were determined somewhat by the steep grades and by the rates at which the dump car could convey mortar to the lining machine rather than by the rates at which the machine could place the mortar lining; which latter rate was slightly more than 3 linear feet per minute for $\frac{1}{4}$-inch lining and slightly less than 2 linear feet per minute for $\frac{5}{8}$-inch lining. As the lining machine approached the mixing plant, shortening the length of run of the dump car, it was necessary to use two mixers to keep the machine supplied with mortar.

SELECTION OF SAND AND CEMENT

The contract specifications pertaining to sand, cement and water for the mortar lining were as follows: Mortar for the lining shall be a mixture of Portland cement and screened sand and shall be of the proper consistency to provide a dense, homogeneous lining which will hold itself firmly against the pipe surface; and the water-cement ratio shall be carefully controlled. Due allowance shall be made, as necessary, for moisture existing or collecting on the walls of the pipe. Cement shall conform to A.S.T.M. specifications C-I-30. Sand shall be clean, sharp, graded, free from organic matter and with no grains larger than will pass a 12-mesh screen. The proportions of

cement and sand in the mortar for the lining shall be one to three parts of Portland cement to one part of screened sand by volume. The mortar shall be mixed by machine for a sufficient length of time to obtain maximum plasticity, in general for at least five (5) minutes, and shall be used promptly for lining the pipe. No mortar which has attained its initial set shall be used.

In preparation for the cement lining work two of the first considerations were the selection of the sand and the brand of cement to be used.

Previous experimental work over a period of several years had determined the general characteristics of the sand which gave best results. The Contractor's source of supply was a sea-side sand from Jamaica Bay, Long Island, N. Y. Two typical analyses showed the following characteristics:

	percent	*percent*
Mineral passing 200 mesh sieve	1.01	0.72
Mineral passing 100 mesh sieve	6.44	6.58
Mineral passing 80 mesh sieve	10.25	9.97
Mineral passing 50 mesh sieve	46.87	39.53
Mineral passing 30 mesh sieve	30.39	40.00
Mineral passing 20 mesh sieve	3.46	2.76
Mineral passing 12 mesh sieve	1.58	.44
Total	100.00	100.00
Specific gravity of mineral	2.666	2.665
*Weight solid mineral	166.36	166.30
*Weight loose, dry sand	94.34	93.69
Voids, loose, dry sand, percent	43.3	43.7

* Pounds per cubic foot.

From a consideration of the chemical analyses of the fifteen cements, nine were selected as best-suited, chemically, for the work. Because, for its hydration (setting and subsequent hardening) cement relies almost wholly upon its calcium oxide (CaO) and its silica dioxide (SiO_2), as large an amount as possible of these was desired. Cements low in iron content (Fe_2O_3) and in magnesium MgO were given preference. As contraction of the mortar was a very important matter, especially when it is appreciated that 48-inch diameter pipe has a circumference of about 12 feet and the thickness of lining might be as little as $\frac{1}{4}$-inch, a normal aluminum content

(Al_2O_3) was desired as helping to prevent contraction and the formation of cracks in the mortar lining.

After analyses and tests of this and other sands, the contractor's sand was accepted for the work.

Samples of fifteen different Portland Cements were submitted by the Contractor, designated only by a number. These were subjected to the customary standard tests; fineness, specific gravity, soundness, initial and final setting times and tensile strengths with standard Ottawa sand. Tensile strength tests with samples of sand proposed for use were also made. Chemical tests were made for silica (SiO_2), lime (CaO), alumina (Al_2O_3) Samples were tested for low-solubility; non-leaching, minimum-shrinkage and slow-setting qualities which were deemed necessary for a mortar which was to be applied from $\frac{1}{4}$ to 1 inch thick on the interior of the pipes.

From physical tests of these nine cements, best suited for the work from their chemical characteristics, four approved cements were finally chosen. Of the physical tests the chief consideration was the time-of-set. Since the mixing of the mortar, the transporting of it into and through the pipe, its application to the pipe and its troweling and finishing to a smooth surface required more than the ordinary amount of time it was thought best that the cement recommended should have a long time for initial set as well as a long time for final set. Satisfactory tensile strength when mixed 1 to 1 with the approved sand was also a requirement.

Four cements were finally certified to the Contractor as best suited for the particular special work, from which the Contractor made his selection of brand. One brand was used for the entire work. Each carload as received on the work was sampled and subjected to A.S.T.M. standard test. To avoid any possibility of lumps of cement, pieces of bag twine or wire, or other foreign substances clogging or injuring the lining machine all cement was passed through a 16-mesh screen and was then rebagged. Sand was heated and dryed, passed through a 12-mesh screen and bagged. Each bag of sand and of cement contained 85 pounds. This facilitated the making of the mortar mixture which was 1 to 1 by weight.

As the mortar applied to the interior of the pipe was to be kept moist during curing only enough water to completely hydrate the cement in the mortar was considered desirable in order to reduce shrinkage of the mortar to a minimum. This was carefully determined in the laboratory and rigidly adhered to throughout the work.

The water-cement ratio of the mortar was 0.32. The density of the finished lining is shown by the results of tests made on samples cut from the lining about a month after it was placed, showing a volume specific gravity of 2.29 and a water absorption of 5.53 percent of the dried sample as determined by A.S.T.M. D-30-18. Twenty-eight day tensile strength tests of the 1 to 1 mortar averaged about 825 pounds per square inch.

HYDRAULIC RESULTS OF RECONDITIONING

As yet it has been impossible to make tests to determine the effect of the new bituminous enamel lining on the carrying capacity of the reconditioned lines.

It is believed that the lining of the section of 48-inch riveted steel pipe line with cement mortar lining has given it a greater carrying capacity than it had even original, when new. A measure of the ability of a pipe to carry water is given by its so-called Williams-Hazen Coefficient. For instance, if the value of this coefficient, designated as C, is 100 its capacity is twice as much as the capacity of pipe of the same size whose C is 50. The first records which we have from test made of this line to determine the C of this pipe were obtained in November, 1923, when the pipe was 27 years old. They show values of C equal to approximately 80. From time to time between 1930 and 1935 similar observations were made which showed progressively lessening values of C to 70 when the reconditioning work was undertaken, figure 7.

Upon the completion of the machine cleaning of the line preparatory to the placing of the cement lining, a section of the cleaned line about 12,000 feet in length was observed to have a coefficient of about 110. This is probably an indication of the coefficient of the pipe when new. Because of the fact that the 48-inch riveted pipe has short courses about 7 feet in length with tapered sections, lapped joints and full rivet heads on the inside of the pipe it seems unlikely that the value of C was ever more than 110.

Tests of a finished section of the cement lined pipe show a coefficient of 124. The tests were very carefully made in a stretch of pipe 16,000 feet long, lined for the most part with $\frac{1}{4}$-inch cement-mortar lining. The coefficient is based on the 48-inch nominal diameter of the pipe and not on the actual reduced diameter of the lined waterway. It is evident from this, that the smoother contour of the cement-lined surface lessens the disturbances in the flowing stream more than

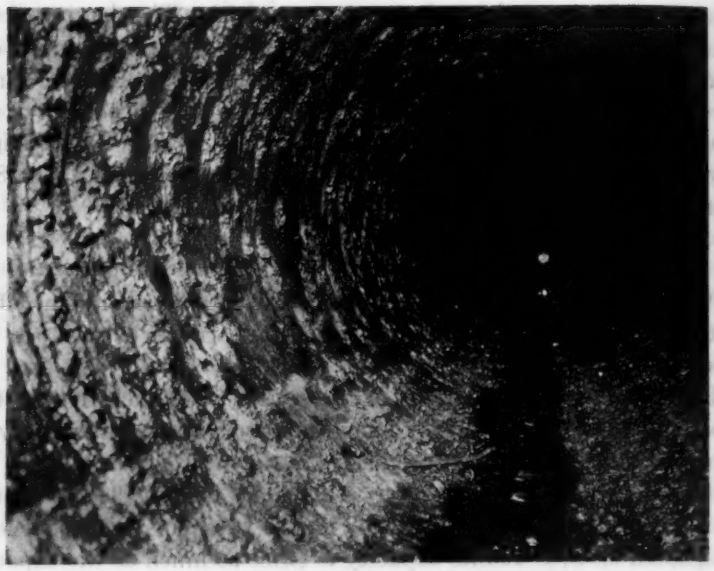

FIG. 7. PIPE LINE BEFORE RECONDITIONING

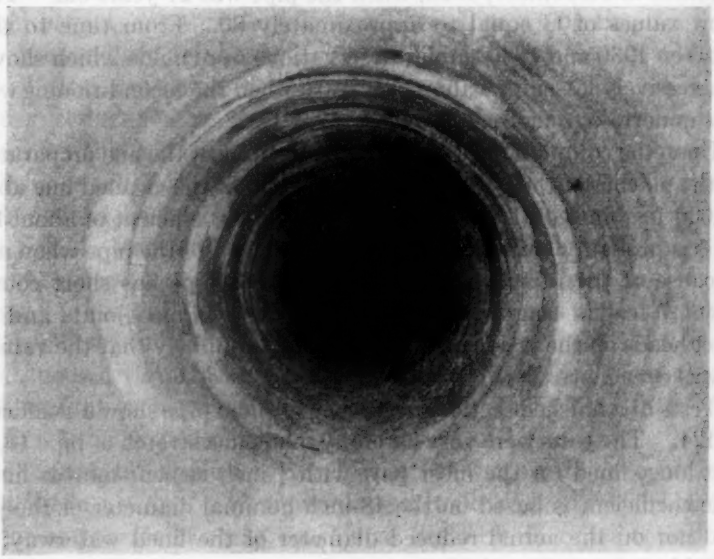

FIG. 8. PIPE LINE AFTER RECONDITIONING

enough to offset the reduction in area of waterway, resulting in a net increase in capacity over the capacity of the cleaned unlined pipe.

As to what thickness of cement lining will result in the greatest capacity and the largest value of C, is one of the fine points of the procedure which remains to be determined. It is hoped that a section of pipe of this same character, with a thicker mortar lining, will be available in the near future and of sufficient length to give values of C with sufficient accuracy to indicate the answer to this interesting hydraulic feature of this very unique procedure.

DISCUSSION

FRED B. NELSON (*Department of Water Supply, Gas and Electricity, New York, N. Y.*): The maintenance of capacity in any water supply or distribution system is an essential factor in proper and satisfactory public service. In small communities, the provision of adequate fire protection capacity may take care of domestic and commercial use, while in very large communities capacity that will take care of the domestic and commercial consumption may, at the same time, satisfy fire supply requirements. In any case, capacity should be provided and maintained to meet all peak demands.

Supplied from an equalizing reservoir, a distribution system of adequate capacity will take care of hourly peak demands, but the hot weather or other high consumption demands that are prolonged call for capacity in the conduits between the storage and equalizing reservoirs.

The paper presented has completely described a novel and economical method of restoring to probably better than original the capacity of such a main which had decreased probably 40 percent in a period of years in which consumption demands have no doubt materially increased. Considering the cement lining used, which I understand has been severely tested under distortion for cracking and bonding with the pipe wall, it would seem that over a period of future years the restored coefficient and capacity should remain constant instead of decreasing, as would be expected with the original or a new pipe.

By rehabilitation, the coefficient or capacity is being raised from 70 to 124, or 77 percent. The increase of capacity corresponds approximately with the capacity of a new 30-inch paralleling the old 48-inch at but a fraction of the cost of such a main. The postponement of interest and amortization charges on the cost of a large

conduit that otherwise would now be required, would undoubtedly show a handsome saving to the credit of the reconditioning.

This serious situation met and corrected in this case is one of depleted and inadequate capacity in supplying the prolonged consumption demand under a constant or fixed slope between reservoirs. The improvement in increased delivery is, therefore, directly proportional to the increase in coefficient obtained.

In a long main, or mains, supplying a large area of distribution, the maintenance of flat gradients and thereby stabilized pressures under hourly peak demands is the important objective fully appreciated by only those whose business is the maintenance of proper pressure service. In such cases, the drop in service pressures on any given high demand varies inversely as the *square* of the capacity or coefficient.

For example, using for convenience the simple formula of $V = C\sqrt{r.s.}$, the velocity (V) corresponding with a given demand and the hydraulic radius (r) remain constant, and the drop in pressure (s) varies therefore inversely as the *square* of the improvement in the coefficient (c).

Were the main under discussion being thus used to supply distribution, the drop in pressure after reconditioning on the area supplied under a given demand would be $\left(\frac{70}{124}\right)^2$, or close to one-third the original drop. If we assume the main were supplying a section of distribution having a not unusual drop of, say, 15 pounds from the maximum night time pressure to the minimum pressure at morning peak demand, the pressure drop would be decreased due to reconditioning from 15 to 5 pounds, representing an improvement of 10 pounds on service pressure at the time when the water is being used and service pressure most needed. If in the same hypothetical area the supply is pumped and the peak demand conditions compensated for by increased discharge head at the station, then, conversely with the reconditioned main, peak load service pressures can be maintained with 10 pounds lower lift at the pumps and consequent daily saving in power or fuel costs.

In this very general discussion, I am aiming to emphasize the importance in proper distribution service of providing and maintaining ample capacity:

(1) In long conduits leading to the equalizing reservoir or distribution system to avoid decreased supply under prolonged

high consumption demand, in which case the rate of supply varies *directly* as the coefficient maintained.

(2) In major trunk mains supplying the distribution system to avoid unserviceable pressures at times of peak demand when the drop in pressure varies inversely as the *square* of the coefficient maintained.

The authors of the paper should be complimented in having given a very complete presentation of novel but promising methods of accomplishing these objectives.

LABORATORY CONTROL OF PROTECTIVE TREATMENT OF STEEL PIPE LINES BY THE BUREAU OF WATER WORKS AND SUPPLY OF LOS ANGELES

By Harry Hayes

(Assistant Engineer, Bureau of Water Works and Supply, Los Angeles, Calif.)

The purpose of this paper is to present to the members of the American Water Works Association the methods used by the Bureau of Water Works and Supply for selecting, testing, and applying the materials which it uses for the protection of its steel water mains against corrosion.

In the field of protective coatings, it is quite generally agreed that the hot-application asphalts and coal tars constitute the most serviceable media for the protection of buried or submerged steel. It is also quite generally conceded that the coal tar enamels are superior to the asphalts in protective qualities provided the structure coated can be installed with the coating intact and undamaged. But the coal tar enamels available in the past have been difficult materials to handle because of their low range temperature susceptibility and low ductility. Unlike the asphalts, these enamels, when exposed to summer temperatures would soften and sag, and in temperatures slightly below freezing would crack and spall off the coated structure. In addition the enamels were so brittle at ordinary temperatures that extreme care in handling the coated structure during installation was necessary to prevent injury to the enamel.

Quoting from a previous contributor to this publication:

> "In general, asphalt coatings are superior to coal tar coatings. The asphalt coatings are pliable, do not become brittle or check at low temperatures, sag or flow at summer heat, possess the necessary flexibility and toughness to withstand wear and tear encountered in transit and during installation, and have sufficient ductility to resist movement of installed pipe. Inasmuch as these qualities are lacking in coal tar coatings, it is much more difficult to procure satisfactory installed pipe with coal tar coatings than with asphalt coatings, but if an undamaged coal tar coating is obtained after installation, it will be more resistant to disintegrative action of water and other corrosive influences than asphalt coatings."[1]

[1] Journal, 25, 10, October, 1935.

This quotation sums up the situation as regards these two types of protective coatings prior to about three years ago.

In the last three years, developments in the coal tar coating industry have produced enamels in which all the objectionable features above referred to have been eliminated. This has been done through the use of a new type of so-called "Plasticised" coal tar pitch that is a product, not a by-product, of the coal tar industry. Enamels made from this new type pitch will withstand temperatures of 160°F. continuously for 24 hours or more without sagging, will withstand tem-

FIG. 1. A CORNER OF THE BUREAU'S COATING LABORATORY SHOWING THE ELECTRIC CONTROL PANEL AND TAR POTS

Both gas and electric tar pots are used

peratures as low as 20 to 30 degrees below zero without cracking and have a ductility approaching that of asphalt coatings. They will retain these characteristics when made in a relatively soft coating, admiredly suited to application by centrifugal casting for inside lining, or when made into hard and tough exterior coating that will resist soil stress in the most severe soils in which water mains are laid. In addition, they retain all the excellent corrosion resistant properties of the old type coal tar coating.

The latest development, which has occurred within the year, is

in the manufacture of the primer used with coal tar enamel. Primers used in the past, regardless of quality or care used in application, have had a very weak bond strength at temperatures only slightly above normal. Due to the low melting point pitch of which they are made, these primers are soft enough at any temperature above 100°F. to allow the enamel to be pulled off in a sheet, or even to sag off under its own weight. In the new primer now available, this undesirable feature has been eliminated and it is impossible, even at 150°F., to strip off in a sheet an unreinforced enamel from steel

FIG. 2. SPRAYING TEST PANELS WITH COAL TAR PRIMER
An exhaust fan above the canopy removes all smoke and fumes

primed with this primer. The advantage of a primer of this nature is obvious when it is considered that it will effectively prevent stripping under heat either from high summer temperatures or from electric or torch cutting and welding, and will also lessen the hazard of rupture during transportation in warm weather.

It is the present practice of the Bureau to coat both surfaces of all underground steel pipe and the inside surface of all exposed pipe with this new type coal tar enamel. The enamel and its requisite primer are purchased on open bids under specifications designed to obtain this new type enamel. In order to eliminate from consideration the

old type enamels and cheap competitive materials, these specifications require that all material submitted, either as bid samples or contract shipments, be subjected to rigid tests designed to reveal the characteristics above referred to.

TESTS

These tests, referred to as "Performance Tests," were developed in the Bureau's Laboratory particularly for bid and shipment sample testing. They consist of the following:

1. High Temperature Sag Test.
2. Low Temperature Cracking Test.
3. Cold Bend Test.
   a. On Initial heating of enamel.
   b. After 1½ hours continuous heating of enamel.
4. Soil Stress Test.
5. Stripping Test.

In addition to the performance tests, certain physical test requirements are included in the specifications. These are the tests pertaining to coal tar enamel that have been standardized by the American Society for Testing Materials and they include the following:

1. Softening Point, Ring and Ball Method A. S. T. M. Serial Designation D–36–26.
2. Penetration
   a. At 77°F.
   b. At 115°F.
   A. S. T. M. Serial Designation D–5–25.
3. Ash
   A. S. T. M. Serial Designation D–271–33.
4. Specific Gravity
   A. S. T. M. Serial Designation D–71–27.

These tests, with prescribed limits, are included particularly as a guide to bidders. Although they are of prime importance to the manufacturer in the control of production, they are of little significance to the water works engineer in terms of the service that may be expected of the material. Nor do they differentiate between various grades of material because two enamels having identical physical characteristics will not necessarily perform identically.

The performance tests are practical tests based on the obvious requirements of a good protective enamel. Although they are not difficult tests to make, they require careful and experienced operators.

When completed, the results show a picture that can be understood by the lay operator, and correlated to field requirements without requiring advice and interpretation from expert technicians.

The high temperature sag test conducted at 160°F. and the low temperature cracking test at −10°F. are the two tests which differen-

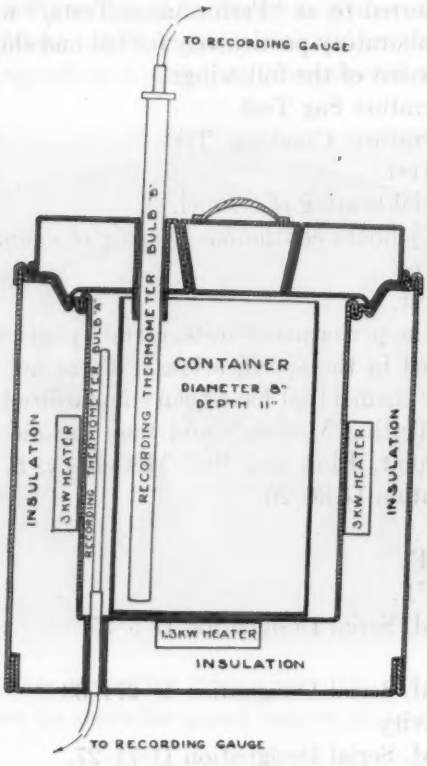

FIG. 3. A CROSS-SECTION DRAWING OF THE ELECTRIC TAR POT USED FOR HEATING ENAMEL

tiate between the new ductile enamels and the old brittle material. While it may be possible to process the old type pitch enamel to a point where it could be made to withstand either one of the above temperatures, it could not, whether it were an honestly compounded material or a cheap competitive article, be made to withstand both temperatures in the same material.

Why should we be concerned with such extreme temperature conditions in Southern California where the temperatures seldom go above 100°F. or below 32°F.? Consider the high temperature requirement. A piece of bare or black coated steel lying in the sun will absorb sufficient heat to raise its temperature to 150°F. or above, with the recorded temperature at 95° to 100°F. It is obvious that any material that cannot withstand this high temperature would be impractical to use, particularly in summer weather, as any such coating would be ruined by handling alone. Even the new type

FIG. 4. APPLYING COAL TAR ENAMEL TO TEST PANELS WITH A NO. 2 TAMPICO FIBER DAUBER

enamels are whitewashed to reduce this high temperature hazard. As to the low range requirement, it must be considered that the test is for unstressed cracking. It has been found through field experience that this specified temperature is none too low to prevent cracking and shattering due to rough handling at temperatures below 40°F. The high quality performance required of an enamel in these and in the cold bend test is considered a factor of safety against the rough usage it will receive in the field.

The cold bend test is the most accurate indicator of toughness and adhesion of an enamel coating that has been used in the Bureau's

Laboratory. It not only shows macroscopically the degrees of these properties, but gives quantitative measurements that are not possible with other tests. The test will also show the change in an enamel due to prolonged or overheating or to the addition of as little as one quart of flux to a barrel of enamel. This test used in connection with the soil stress test has been instrumental in developing a higher grade enamel commercially than was formerly available.

The soil stress test was first used in making soil stress surveys along proposed pipe line routes. It is not a test that is original with the Bureau, but one that has been adapted to its purposes. With this

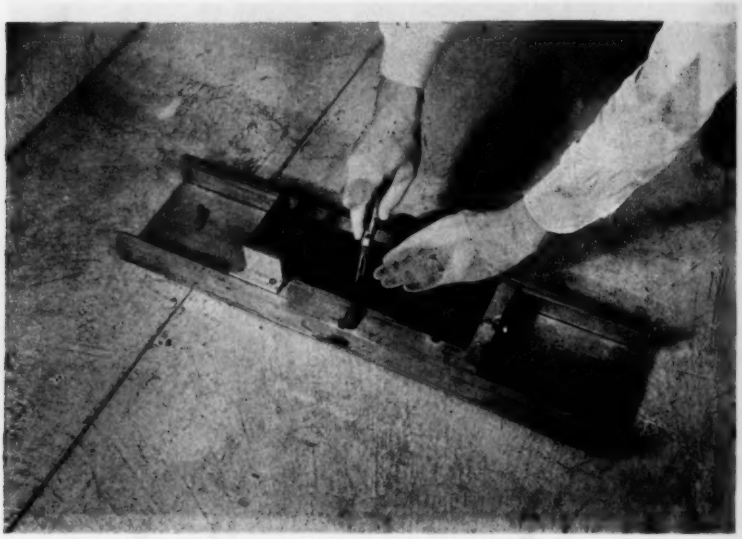

FIG. 5. SCRIBING SAG LINES ON A HIGH TEMPERATURE TEST SPECIMEN

test it is possible to determine the relative rupturing strengths of the various soils in which a line is to be laid and to determine the type of coating necessary to resist the most severe condition. Specifications are then written on this type of coating, and included in them is the result of the soil stress test on the most severe soil.

The stripping test was developed particularly for the purpose of determining the relative bonding strengths at high temperatures of the new type of heat resisting primers, and has no counterpart in the tests of the old type primers. It is strictly a comparative test, being based on the time required for a given weight to pull a strip of enamel from a primed and coated plate while held at a high temperature.

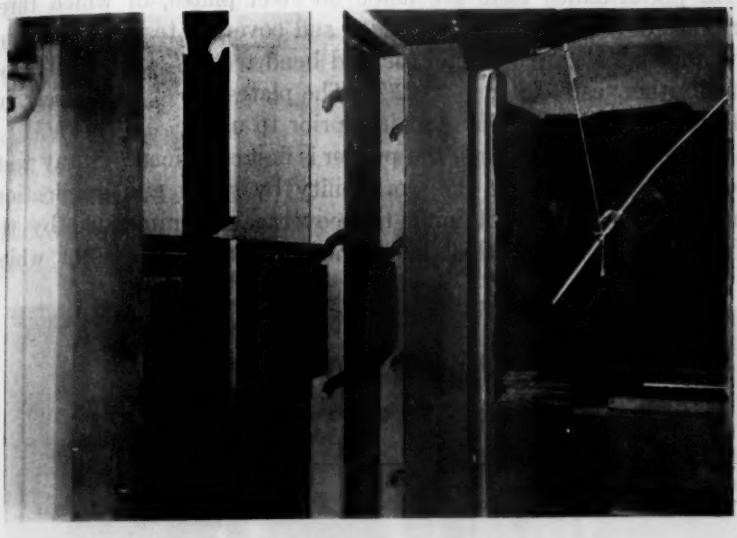

FIG. 6. HIGH TEMPERATURE SAG TEST

The room is heated electrically and maintained at a uniform temperature by a thermostat and air circulating fans. The thermometer bulb of the temperature recorder-controller is suspended in the center of the room.

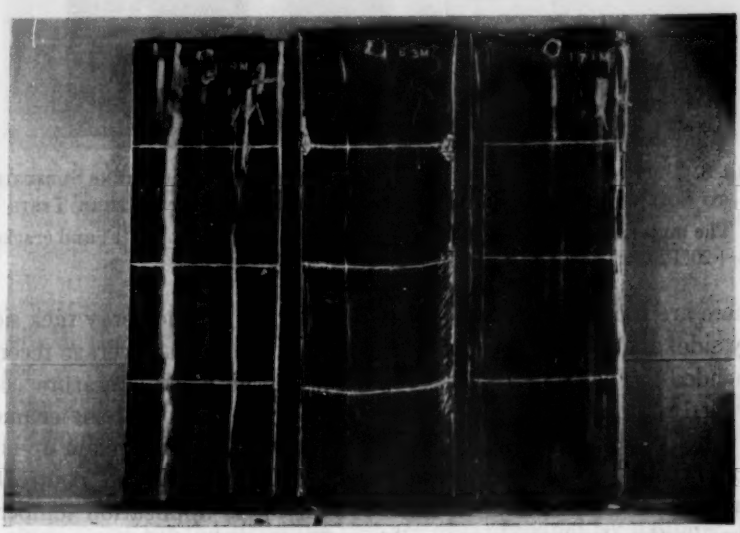

FIG. 7. HIGH TEMPERATURE TEST SPECIMEN. SPECIMEN SUBJECTED TO 150°F. FOR 24 HOURS

Note sag on Panel 63 M

All performance tests are made on steel plates, of which three sizes are used. For the workability and coverage tests, one foot by four foot panels are used; for the cold bend test $\frac{1}{16}''$ x 4" x 10", and for all other tests $\frac{3}{16}''$ x 4" x 12". The plates are of mild steel, and all are thoroughly sandblasted just prior to use.

In making routine tests, the primer is first examined. Spray tests are made to determine the workability by spray gun application, and for practice in obtaining the coverage recommended by the Manufacturer. With this determined, the test panels, of which

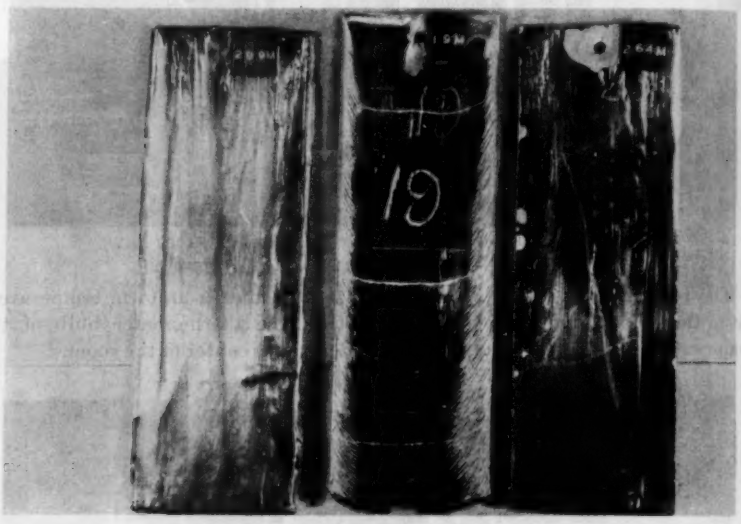

FIG. 8. TYPICAL TEST SPECIMEN OF OLD TYPE ENAMEL. SPECIMENS SUBJECTED TO SOIL STRESS, HIGH TEMPERATURE AND LOW TEMPERATURE TESTS

The material was unaffected by soil stress, but sagged at 150°F. and cracked at +20°F.

there are four to six for each test, are laid out on the spray rack side by side, and all very carefully coated with the exact coverage recommended. They are then stored in a ventilated temperature controlled room at 70°F. for 24 hours before application of the enamel.

About twenty pounds of the enamel to be tested is broken up into small pieces and charged into electrically heated and controlled tarpots, where it is melted and brought up to application temperature in the shortest time possible. The length of time required to heat a batch of enamel is important, and has been standardized for

all enamel testing where comparative results are desired, as any material difference in the heating time will affect the test results, particularly of the cold bend test.

The enamel is applied either by dipping or daubing, depending on the test for which the specimens are to be used. For the high and low temperature tests and for the cold bend test, application is by daubing using a No. 2 Tampico fiber dauber. The plates are laid side by side in a daubing rack and coated solid as though in one piece. In this manner a whole set of panels are coated at one time,

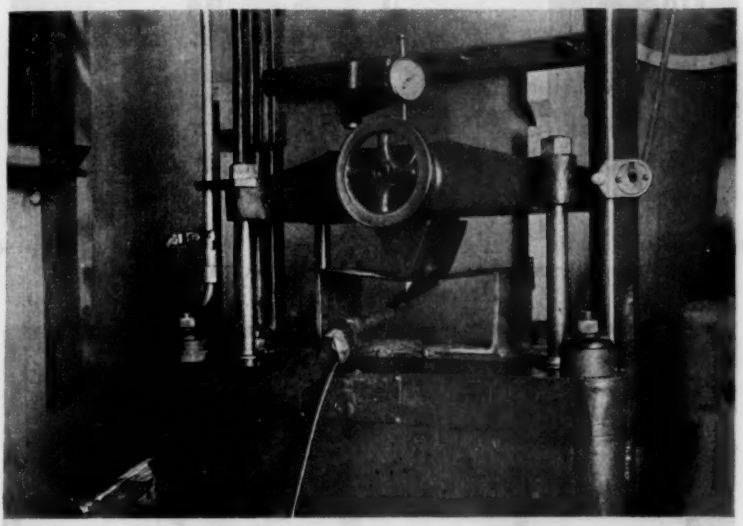

FIG. 9. COLD BEND TEST. SPECIMEN BEING SUBJECTED TO BENDING AT 40°F. Note the high tension spark passing from the Detector brush to the panel through a crack in the enamel.

permitting a more uniform coat than would be possible if coated individually. Special efforts are made in all cases to obtain a uniform coat of from $\frac{1}{16}''$ to $\frac{3}{32}''$.

For the soil stress test the panels are coated by dipping as it is necessary to have a continuous coating around the edges and back of the plate, otherwise the severe soils will tear the enamel off the plates.

Specimens for the stripping test are also prepared by daubing, but in this case a reinforcing membrane is laid in between successive

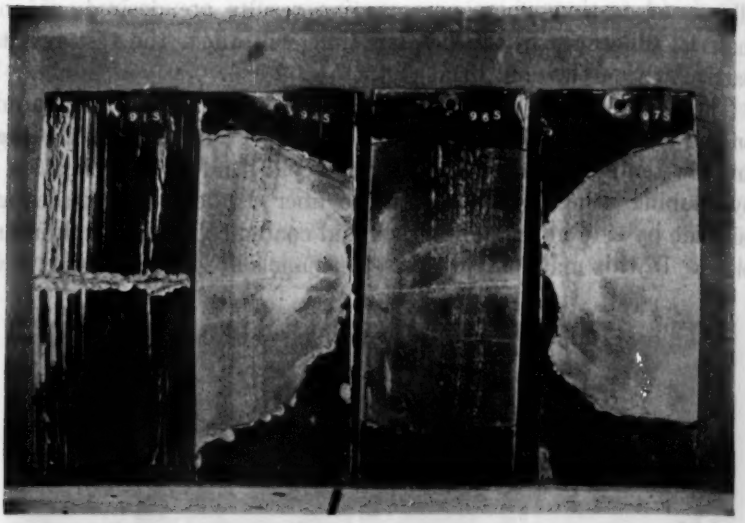

FIG. 10. COLD BEND TEST SPECIMEN. SHOWING THE EFFECT OF A $\frac{3}{4}$-INCH BEND ON THE NEW AND OLD TYPE COAL TAR ENAMELS

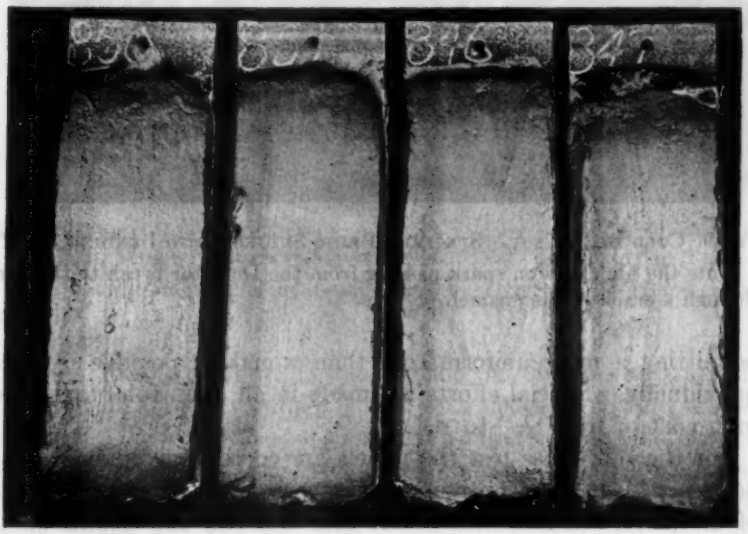

FIG. 11. SOIL STRESS TEST SPECIMEN

The soil is moistened to a plastic consistency and troweled onto the enamel surface.

coats of hot enamel. The purpose of the membrane is to prevent tearing of the enamel during the stripping process.

When the panels thus prepared are cooled sufficiently to stand handling they are separated, trimmed and placed in temperature controlled rooms maintained at the temperatures at which the tests are conducted.

The low temperature test specimens are placed directly in the refrigerator where the temperature is held at −10°F. After eight hours they are removed and examined for evidence of cracking,

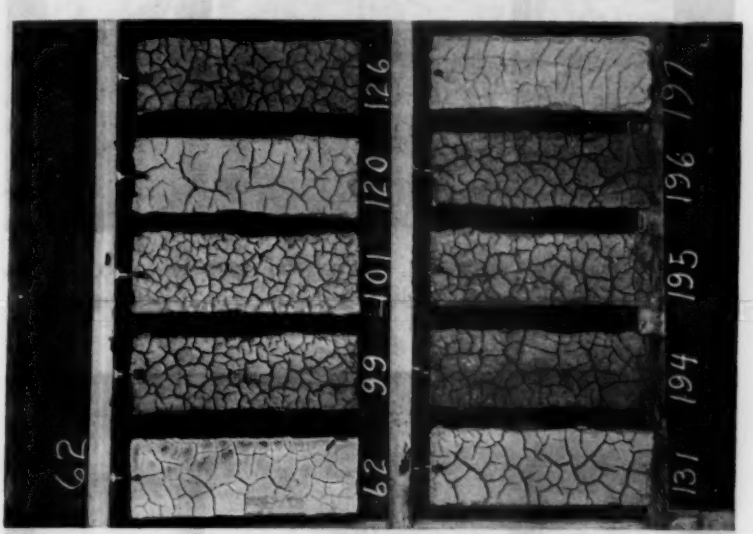

FIG. 12. SOIL STRESS SPECIMEN. APPEARANCE OF TYPICAL SOILS AFTER DRYING

The soil is dried out in a ventilated room at 70°F.

both visionally and with an electrical flaw detector. Usually, however, an enamel that will crack at a low temperature will loosen and fall off the plate.

Before testing the high temperature test specimens they are marked with three equally spaced lines scribed in the enamel across the plate and the lines filled with chalk dust. The specimens are then hung vertically in the temperature room and held at 160°F. for 24 hours. Any sag occurring in the enamel may be easily detected by the movement of the lines.

FIG. 13. SOIL STRESS SPECIMEN. SHOWING EFFECT OF A SEVERE SOIL
A relatively soft enamel is used for testing and classifying soils

FIG. 14. SOIL STRESS TEST SPECIMEN. SHOWING EFFECTS OF MODERATE AND MILD SOILS

For the cold bend test the Bureau uses an Olsen Universal Testing machine that is conveniently placed in a temperature controlled testing room. The cold bend panels are stored in this room, with the temperature regulated at 40°F. for at least four hours prior to testing. The test consists of subjecting the panels to transverse bending using a 9½ inch span with a center point loading, bending the panels to produce tension in the enamel. The rate of bending

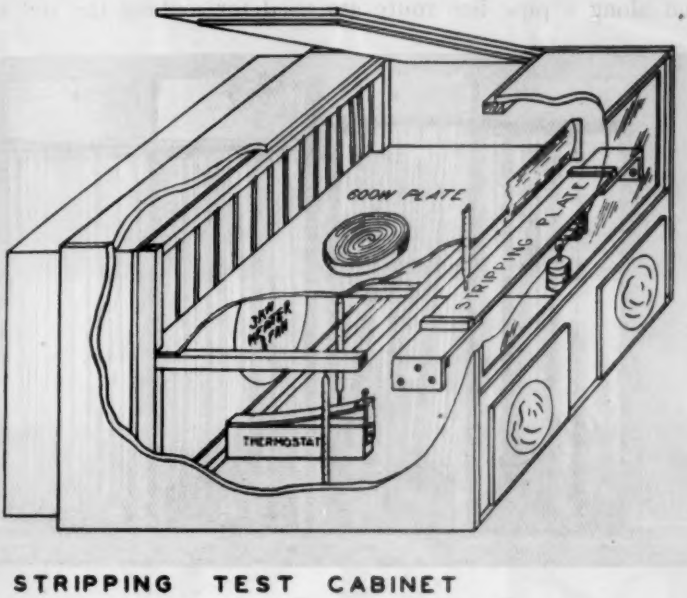

FIG. 15. STRIPPING TEST CABINET

The test is conducted at 150°F. Specimens are placed on the stripping rack, enamel face down, and a 2230 grain weight attached to the loosened end of the enamel. The free falling of the weight strips the enamel from the plate.

is regulated to produce a uniform rate of deflection of one inch per minute at the center of the span. During the bending the high tension brush of the electrical flaw detector is held in contact with the enamel at the center of the plate. The instant a crack occurs in the enamel due to the bending, the high tension spark jumps through the break, indicating the initial cracking. Measurement of the deflection for initial cracking is made with a dial gauge arrangement attached to the machine.

The bending is continued until a total deflection of $1\frac{1}{2}$ inches is attained. If a crack is produced in the bending, the extent of loosening of the enamel from the plate is determined by digging and prying the loosened enamel adjacent to crack and continuing until enamel is encountered which exhibits the original adhesion. The area of the panel exposed by the removal of the enamel is measured with a planimeter directly from the panel.

Soils representative of the most severe condition that have been found along a pipe line route are used for making the soil stress

FIG. 16. STRIPPING TEST SPECIMEN

A reinforcing membrane is imbedded in the enamel. In preparation for the test, the panel ends have been heated and the enamel pulled back with a hot knife and folded over to provide an end to which a weight clamp is attached.

tests on the enamel that is to be purchased for that line. The soil is mixed with water until it is thoroughly saturated and then troweled onto the enameled surface of the test panels to a depth of about $\frac{3}{8}$ of an inch. The panels are then hung in a ventilated temperature controlled room at 70°F. and allowed to remain until the mud on the panels has become thoroughly dry. The saturated condition of the soil is representative of the flooded backfill used in covering the pipe, and the temperature at which it dries is the probable maximum temperature of the water that will be carried in the pipe. Thus the

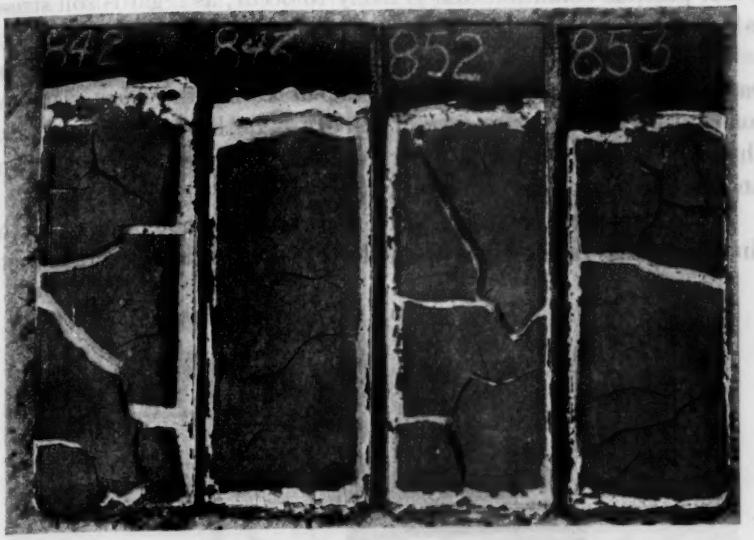

FIG. 17. SOIL STRESS ON WHITEWASHED ENAMEL
Whitewash prevents bonding of soil to enamel

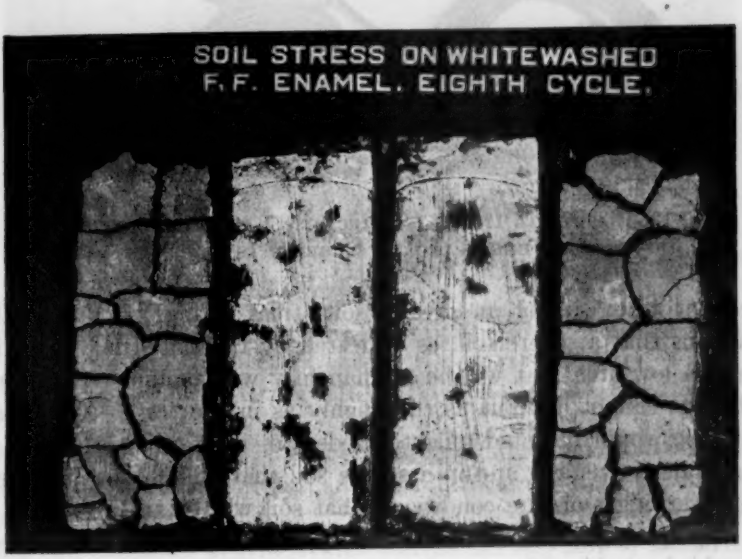

FIG. 18. SOIL STRESS ON WHITEWASHED ENAMEL
A very severe soil was used in this test

worst possible condition that is likely to occur, as regards soil stress, is simulated in this test.

When dried, the mud is soaked with water until soft enough to be easily washed from the enamel. The plates when dried are examined for rupture or other evidence of soil stress both visionally and with the electric flaw detector, and rated in accordance with the extent and depths of the surface rupture.

The rupturing strength of a soil thus found is not necessarily the final soil stress rating given the soil. Field conditions are taken into

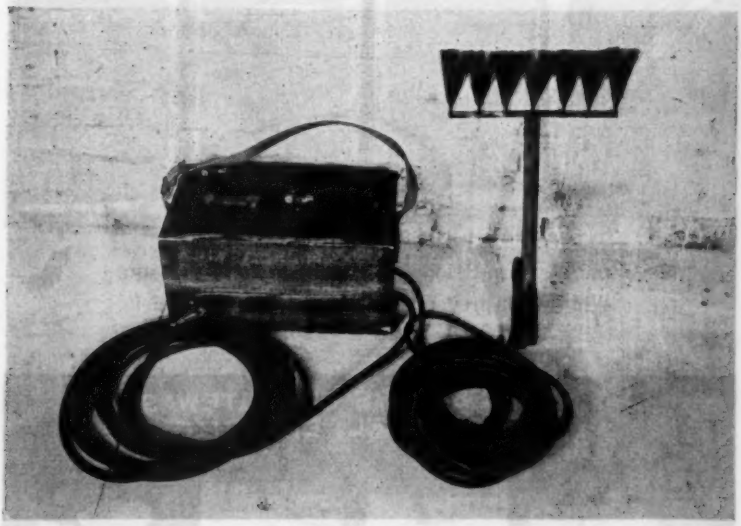

FIG. 19. ELECTRICAL HOLIDAY DETECTOR. BATTERY SET FOR FIELD INSPECTION WHERE ELECTRIC CURRENT IS NOT AVAILABLE

account when giving an area a soil stress rating. It frequently happens that a severe soil, as indicated by the soil stress test, will lie in a low area that will be permanently wet, or under pavement where it cannot dry out as thoroughly as in the test. Such areas as these would be rated mild to moderate. But where the pipe is not under pavement and in a severe soil that will shrink and swell with varying moisture conditions, that soil will be truly severe.

In preparing a specimen for the stripping test, one end of the steel panel is heated in a flame until the enamel is soft enough to be peeled back readily with a hot knife. The knife is slipped between the

enamel and the steel and the enamel peeled off and laid back about two inches. This loosened area provides an end on which to fasten a clamp for suspending weights and for a start of the peeling process.

The panels thus prepared are then stored in the testing cabinet which is maintained at 150°F. for three or four hours prior to and

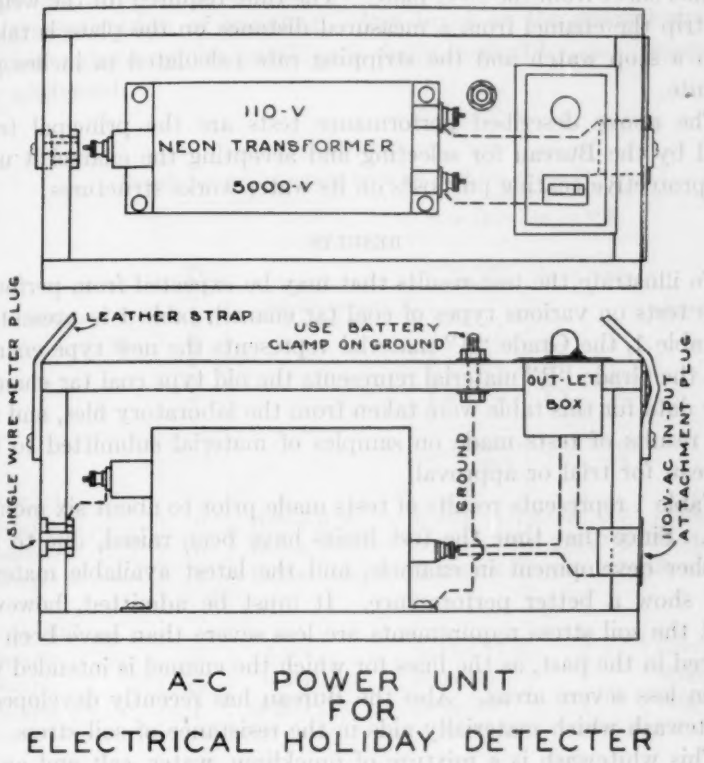

FIG. 20. NEON TRANSFORMER FOR HOLIDAY DETECTOR. FOR USE WHERE ELECTRIC CURRENT IS AVAILABLE

Current switch contains a telltale light to show when set is "Hot"

during the test. The cabinet is an insulated box containing an electric heater, a thermostat, an air circulating fan and the apparatus on which the test is made. In the front of the box is a glass window and two armholes provided with canvas sleeves, and so situated as to give the test operator full view and access to the test apparatus.

In conducting the test, a specimen is placed on a rack where it

rests on two end supports with the coated side down; the weight clamp is then fastened to the loosened end of the enamel sheet and a hanger and 2 K.G. weight (total weight 2230 grams) attached to the clamp. This weight is gently released until it is supported entirely by the enamel, allowing the weight to strip the reinforced enamel sheet from the steel plate. The time required for the weight to strip the enamel from a measured distance on the plate is taken with a stop watch and the stripping rate calculated in inches per minute.

The above described performance tests are the principal tests used by the Bureau for selecting and accepting the enamel it uses for protective coating purposes on its water works structures.

RESULTS

To illustrate the test results that may be expected from performance tests on various types of coal tar enamel, table 1 is presented. In table 1, the Grade "A" material represents the new type enamel and the Grade "B" material represents the old type coal tar enamel. The data for this table were taken from the laboratory files, and are the results of tests made on samples of material submitted to the Bureau for trial or approval.

Table 1 represents results of tests made prior to about six months ago. Since that time the test limits have been raised, due to the further development in enamels, and the latest available material will show a better performance. It must be admitted, however, that the soil stress requirements are less severe than have been required in the past, as the lines for which the enamel is intended will lie in less severe areas. Also the Bureau has recently developed a whitewash which materially aids in the resistance of soil stress.

This whitewash is a mixture of quicklime, water, salt and an oil plastisizer that is applied to the pipe after the completion of the outside coating. Its primary purpose is to protect the coating from absorbing heat from the sunlight, but it will also prevent the severest soil from bonding to and rupturing the coating. Unlike the ordinary lime whitewash, it will not flake and dust off when dry and warm nor will it wash off under continuous spray or water immersion. Repeated cycles of soil stress on enamel coated with this whitewash have failed to rupture the enamel, even on those samples that have been subjected to moisture spray for months prior to the tests. How long this whitewash will hold its protective qualities is not yet

known, but it will at least aid in resisting the first and worst cycle of soil stress, which includes the settlement of the backfill, for it has not failed, nor shown evidence of deterioration in four months of testing.

A third function of whitewash on coated pipe is an aid to field inspectors in locating damages to the coating that may occur during transportation or handling. Any break in the enamel that is deep enough to require patching is easily located by the damage to the whitewash.

TABLE 1

Results of performance tests on coal tar enamels

MATERIAL	SAG 24 HRS. AT 150°F.	TEMPERATURE TO CRACK	COLD BEND TEST AT 40°F.				SOIL STRESS
			Intial heating		After 1½ hours heating		
			Deflection to crack	Shatter area	Deflection to crack	Shatter area	
	inch		*inch*	*square inch*	*inch*	*square inch*	
Grade "A"							
Sample 1	0	Below 0°F.	0.470	1.4	0.300	2.7	Slight
Sample 2	0	Below 0°F.	0.500	1.3	0.270	17.0	Moderate
Sample 3	0	Below −20°F.	0.700	0.0	0.460	0.5	Severe
Grade "B"							
Sample 1	9/16	+5°F.	0.170	17.0			Severe
Sample 2	7/16	+5°F.	0.08	28			Slight
Sample 3	1/4	+20°F.	0.05	16			Slight

Field inspection of the application of enamel to water works structures is a function of the Bureau's laboratory, under the authority of the Field Engineer, Mr. R. R. Proctor. Since the Bureau's coating work is done mostly by force account, this inspection is more in the nature of aid and instruction than of policing. The Construction Divisions in charge of the coating work have always given full coöperation to the Inspection Division as it is the intent of all to attain the highest degree of perfection in the protective coating.

As an aid to inspection the Bureau has developed an electrical method of detecting flaws in a protective coating which it has termed

an Electrical Holiday or Flaw detector. In its original form it consists of a six volt storage battery, a Model "T" Ford spark coil, a wire brush with a wooden handle, and the necessary connecting wires. The battery terminals are wired to the primary of the coil, the wire brush attached to the high tension terminal with a heavily insulated cable, and the coated structure grounded to the coil. With the current on and the brush passed over the surface of the coating, the high tension current will seek out and reveal the slightest flaw or pinhole in the coating, or any spot where the coating is too thin to provide adequate protection.

Where electric current is available on the job for lighting and other purposes a step-down transformer is used to supply the six volt current for the Detector, thereby reducing the weight of the apparatus by fifty pounds or more. More recently a Neon Light transformer has been used, which requires no coil or vibrator, thus simplifying the apparatus. However, the Field inspectors favor the coil type of Detector, as its spark gives a sharper crackle when it jumps, thus facilitating inspection.

This Detector apparatus was developed particularly for inspection on the hand daubing work on the Bureau's 8-foot diameter Bouquet Canyon Pipe Line. On first trial its value was demonstrated by disclosing thousands of pinholes and Holidays in the coating applied on the first few lengths, which were impossible of detection by eye. By constant supervision and training, and the use of the Detector, it was possible to develop the skill of the men applying the coating, so that eventually they would be able to coat whole lengths of pipe with none, or at most, a very few pinholes in the entire coated surface.

In the article in this issue of THE JOURNAL by Mr. L. E. Goit, Chief Draftsman for the Distribution, Construction and Operating Division, the methods used by the Bureau for coating pipe and other water works structures are presented and described in detail. As may be noted in the article, the present methods used are the results of a gradual accumulation of knowledge and experience gained in the handling of bituminous materials. The Bureau has experienced failures, but invariably these failures, as regards coal tar enamel, can be ascribed to faulty application, and have served to show how this material must be handled.

STEEL PIPE CLEANING AND COATING PLANT OF THE BUREAU OF WATER WORKS AND SUPPLY OF LOS ANGELES

By Laurance E. Goit

(*Chief Draftsman, Bureau of Water Works and Supply, Los Angeles, Calif.*)

In 1930 the Bureau of Water Works and Supply of the City of Los Angeles installed 45,000 feet of steel pipe that had been dipped in asphalt coating. Part of this was handled in a horizontal dipping kettle, with the result that the coating was ribbed and lumpy from draining. Then dipping, after pre-heating, in a vertical kettle was specified, and this produced a very fine appearing finish, smooth and of uniform thickness.

During this time observations in the field were indicating that the materials suitable for dipping in a kettle were not as durable as reputed to be, and, especially in wet soil, left much to be desired in protecting the steel from corrosion. Some of our steel tanks were coated on the inside with hard coal tar enamel brushed on hot, the first being done in April, 1929, and many small sections of pipe were coated by hand with such enamel. Tests conducted in our corrosion laboratory confirmed the evidence of our short time observations in the field concerning the relative merits of asphalt and coal tar. We were so convinced of the superiority of coal tar enamel that the 3½ mile long 80- to 94-inch Bouquet Canyon Reservoir pipe was enameled by brushing by hand, on the inside. (See Water Works Engineering, June 26, 1935.) The hand application of enamel with a dauber is expensive, leaves a rough surface, and is extremely hard on the workmen, especially in application to the interior of a pipe. Of course, a man cannot enter a pipe smaller than about 24 inches diameter with a bucket of hot enamel and a dauber. Figure 1 shows a hand enameled job, the checkered effect being produced by the quick brushing of each spot.

For two or three years the problem of improving the method of applying enamel to large pipes as well as getting it applied to the interior surface of small pipes was studied and experimented with.

The Wailes Dove-Hermiston Corporation developed a method of centrifugal application that could be used on the inside of all sizes of pipe. Crude apparatus was built and improved, and changes and development went on so that no two batches of pipe were handled in just the same way. Figure 2 shows a pipe-rolling rig being driven by the rear wheel of an automobile. This equipment is portable, and while crude, produced a very fine job on pipe up to 20 inches diameter.

The planning of the Harbor Trunk Line, 63,000 feet of 31.4 by $\frac{3}{8}$-inch steel pipe to deliver aqueduct water from the center of the

FIG. 1. HAND ENAMELING WITH DAUBER

city to the harbor district, caused the Chief Engineer and General Manager, Mr. H. A. Van Norman, through Mr. W. W. Hurlbut, Engineer of Water Works, to instruct this division to crystallize the various ideas on enamel application and build a pipe coating plant.

Sand blast feeding machines and some other usable equipment were moved from the old blasting plant for the Bouquet Canyon Reservoir pipe line. A space about 60 feet wide and 600 feet long was cleared in the Bureau's Slauson Avenue pipe yard. Portable melting kettles were assembled, runways constructed for storing and handling pipe, drawings were rushed out, construction of rollers, bearings, base structures, gearing, etc. was rushed through the

Bureau's machine shop, and finally the equipment was ready for use. A job of 1,000 feet of 16-inch steel pipe and then 1,500 feet of 24-inch steel pipe were enameled inside and outside.

The running of these short jobs brought to light many desirable improvements, and with the construction of the Harbor Trunk Line definitely approved, the entire plant was torn up and reconstructed in a better location adjacent to the old.

The reconstructed plant, as used for the enameling of the pipe for the Harbor Trunk Line consists of the receiving runways, blast-

FIG. 2. 16-INCH PIPE BEING ROTATED FOR SANDBLASTING BY DRIVE FROM REAR WHEEL OF AUTOMOBILE

ing machine, priming position, drying and storage runway, interior centrifugal enameling machine, exterior enameling machine, testing position, whitewashing position, and storage runway.

SEQUENCE OF OPERATIONS

The general layout and the space allotted to the various functions are shown in figure 3. The entire plant is arranged for the handling of 30 foot lengths of pipe. Lengths as short as 22 feet can be blasted and enameled on the inside without any change, but the spacing of

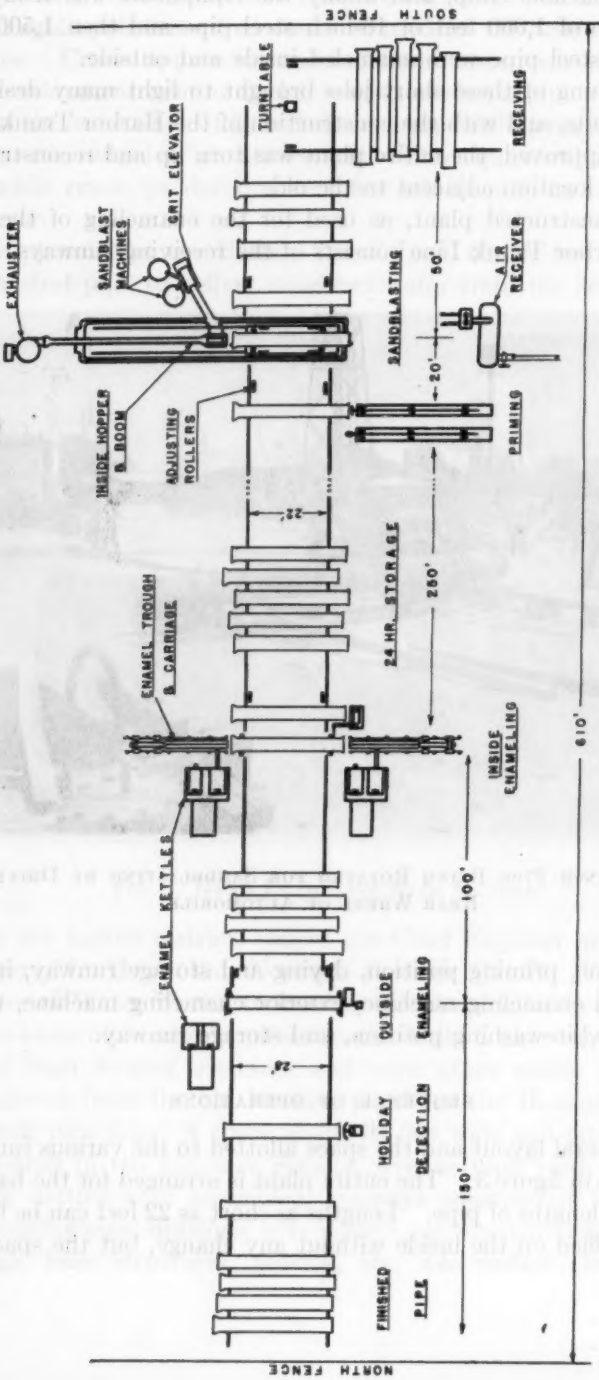

FIG. 3. PIPE CLEANING AND COATING PLANT

the rollers for outside enameling would have to be changed to fit such a length.

The receiving runways are located along the south end of the yard convenient for truck delivery of pipe. Transfer of pipe from the receiving runway to the main line is effected by the use of an hydraulic jack placed at the intersection of the center lines. A section of pipe having been raised by this jack is easily swung 90° by one man, and rolls down the slightly sloping runway when lowered. A cross bolster built up of steel shapes is mounted on top of the ram of the jack so that it is ready to receive another pipe without reversing.

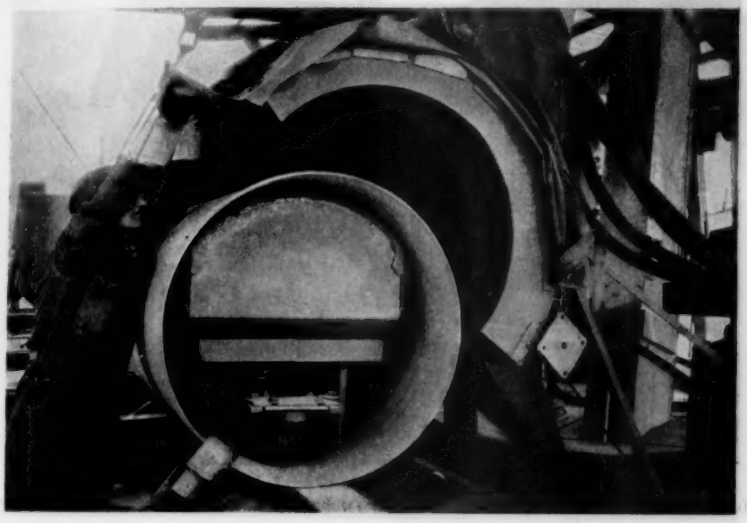

FIG. 4. HOOD CARRYING NOZZLES FOR BLASTING OUTSIDE OF PIPE

The total length of receiving runways is 190 feet, permitting storage of 60 pieces of the 31.4-inch pipe. While on the turntable jack the pipe is entirely in the open giving opportunity to wash off any patches of grease accumulated in the shop. The presence of grease or moisture on the pipe interferes with the efficiency of the cleaning by blasting.

A pipe is rolled from the runway onto a carriage which operates on a transverse track. The pipe is carried on rollers so that the pipe is revolved about its axis at the same time that the carriage moves along its transverse track carrying the pipe past the blasting

nozzles. The revolving of the pipe and the traveling of the carriage are effected by two separate air motors, giving complete control of speeds. The inside and outside of the pipe are blasted simultaneously using # 50 steel grit with 70 pounds air pressure.

The group of nozzles for blasting the outside of the pipe are directed straight down in a hood clearly shown in figure 4. This hood is hinged approximately at the ground line and counter-weighted to give only a light pressure on the pipe. Casters contacting the pipe also guide the hopper. The entire perimeter of the opening against

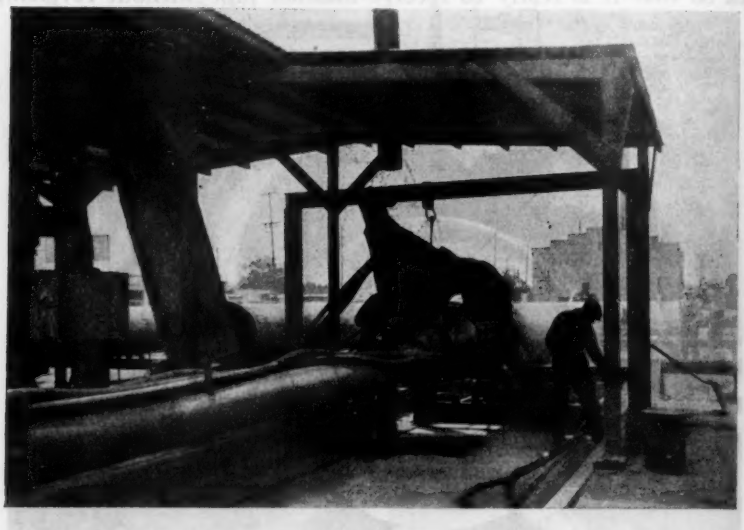

FIG. 5. INSIDE GRIT HOPPER ENTERED IN END OF PIPE, WITH OUTSIDE HOOD RAISED

the pipe carries a rubber gasket mounted to present the edge of the rubber to the pipe. This gasket is quite effective in following irregularities of the pipe and preventing escape of air and grit around the hood. A good grade of pure gum rubber, $\frac{1}{4}$-inch thick, is necessary for this gasket, as ordinary rubber sheet will not stand abrasion. The air and some dust escapes through the vent on the top while the grit slides down the bottom and through a small opening into a hopper below the ground level. The small amount of dust that blows past the gaskets shows in the foreground of figure 6.

The inside blasting nozzle group, directed upward, is mounted in a roughly cylindrical hopper (figures 4 and 5). The grit is confined

in the hopper by means of rubber gaskets as in the outside hood. This gasket is carried by a frame that floats on light springs so that irregularities of the pipe are followed by the gasket. The entire amount of steel grit discharged by the four nozzles for blasting the length of pipe must be retained in the hopper. This hopper is mounted on the end of a 35 foot boom, which is made of 12-inch steel pipe and serves as the air vent from the hopper.

Rubber tired casters attached to the hopper support the weight which increases fast as the grit accumulates from the blasting. In cleaning the inside of a 30 foot length of 31.4-inch pipe the nozzles

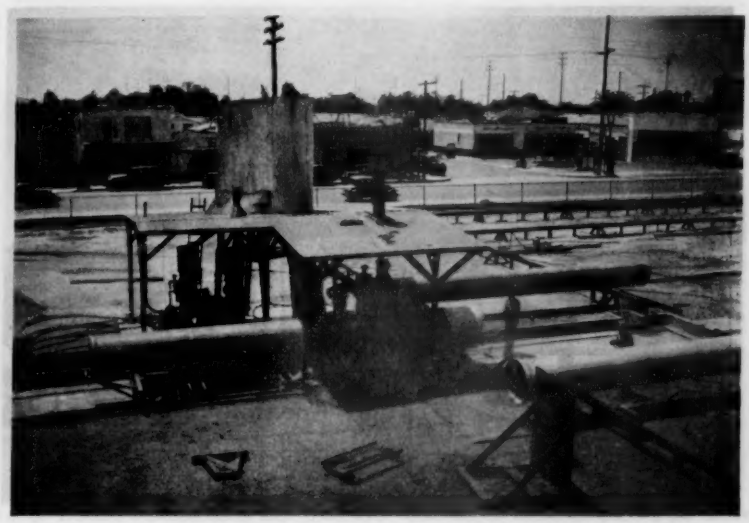

FIG. 6. GENERAL VIEW OF BLASTING EQUIPMENT

discharged about 1,000 pounds of grit. A large door is tightly drawn against the bottom of the hopper by means of a lever arrangement and is sealed by a thick rubber gasket.

After a new pipe is rolled onto the blasting carriage, the carriage is run to the far end of its travel, the hopper entering the pipe, and then projecting through to place the nozzles at the end of the pipe. The outside blasting hood is then lowered, the rotation of the pipe started, and the blast turned on. At this stage the end nozzles are blowing into the opposite hoppers. When one revolution of the pipe is completed, insuring thorough cleaning of the end of the pipe,

the air is turned on for the traversing motor, and the carriage slowly travels along, the blasts making a spiral path along the surfaces of the pipe. When part of the nozzles pass off the end of the pipe, the blast is shut off. A hook, from over-head is attached to the inside hopper to support the weight and the outside hood is raised. The pipe is then run clear and is ready for discharge from the carriage. The trapdoor in the bottom of the hopper is opened, dumping the grit into a chute in the floor.

Hydraulic jacks properly positioned below the blasting carriage track engage hinged frames on the carriage and lift the pipe clear

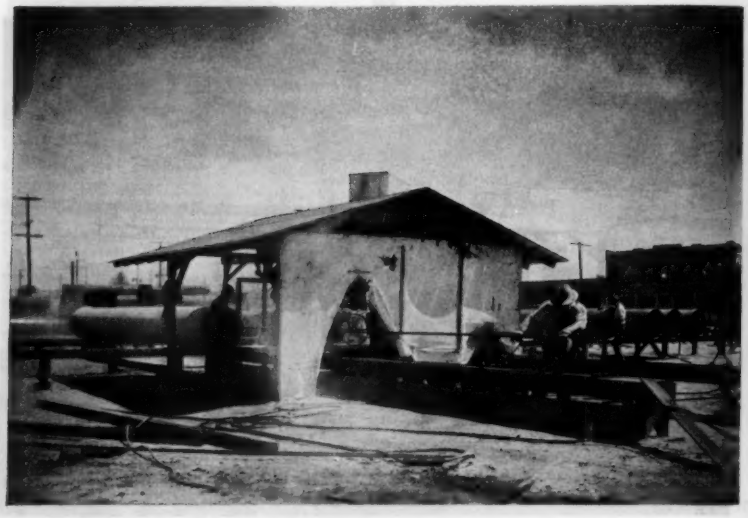

FIG. 7. DRAWING PRIMING SPRAY NOZZLE THROUGH PIPE

of the carriage at the same time starting it rolling along the runway. A small quantity of grit and dust escapes from the inside hopper and this is brushed from the pipes with a long-handled broom followed by air jets.

The pipe is then carefully located before a long table with small channel tracks (figure 7) on which is supported the special spray gun for priming the inside of the pipe, with its 30-foot-long handle and air and paint hoses. The nozzle is run through the pipe to the far end, being kept in the center by wheeled supports at intervals along the long tubular handle. The air and paint are turned on and the nozzle, throwing a circular spray straight out to the pipe surface, is

drawn through at an ordinary walking speed. The inside of the pipe is completely painted with primer in one pass. The outside of the pipe is then primed with an ordinary paint spray gun. Paint is handled in a 30 gallon pressure paint pot with air motor operated agitator. Coverage of the primer is about 600 square feet per gallon.

The pipes are rolled along the runway and held until the next day to permit the primer to dry. The first pipe primed each day bears a marker clamped to the end to identify it. There is runway length sufficient to store 70 pieces of 31.4-inch pipe at this stage.

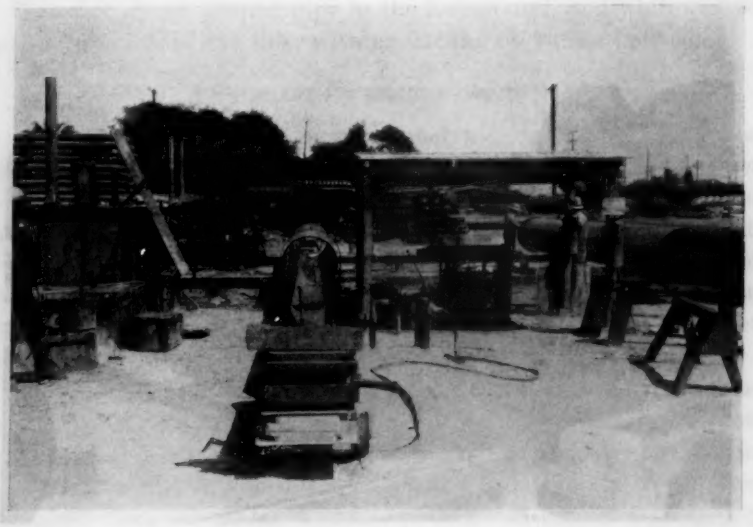

FIG. 8. INSIDE ENAMELING EQUIPMENT. GASOLINE ENGINE DRIVE TO RIGHT AND GAS FIRED ENAMEL MELTING KETTLES TO LEFT

The primer having dried approximately 24 hours, the pipe is ready for coating with enamel.

The first pipe in line is rolled forward to the break in the runway where it drops onto the rubber tired rollers of the inside enameling machine (figure 8). At the same time the hot enamel is being run from the melting kettle into the troughs that distribute it in the pipe. The clutch of the driving engine is let in and the pipe is brought up to the proper speed of 930 feet per minute linear surface speed which required 110 rpm. for 31.4-inch pipe. As soon as the proper speed is reached, one trough, long enough to reach the center of the pipe, is run in from the end and dumped. The other trough

is then run in from the other end to slightly over-lap the first, and dumped. The rapid revolution of the pipe distributes the liquid enamel smoothly over the inside surface, and then water sprays are turned on to accelerate cooling. The thickness of this enamel coating is very uniform. We use a thickness of about 0.11 inch, which amounts to 0.86 pound per square foot. Figure 10 shows the perfection of the coating obtained by this process. The spinning of the pipe is then stopped, and the pipe discharged from the machine by hydraulic jacks, and rolled toward the outside coating machine.

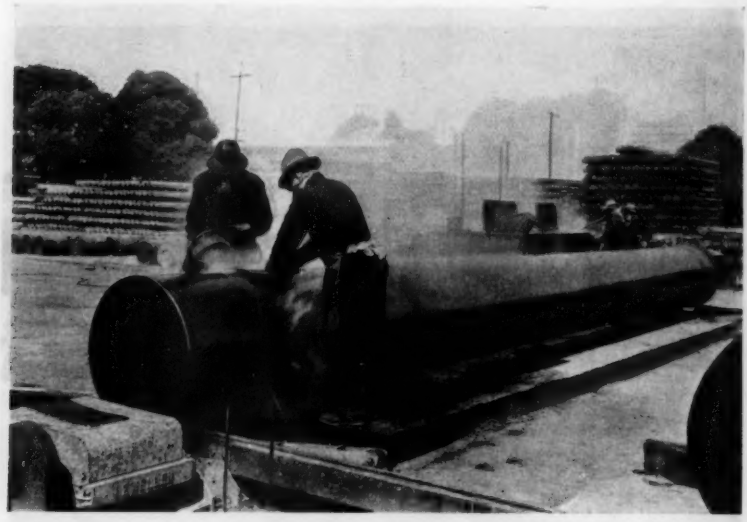

FIG. 9. ENAMEL BEING SPREAD BY PAD HELD AGAINST REVOLVING PIPE

Here the pipe is again carried on rollers and revolved by electric power, but at a surface speed of 165 feet per minute, or 20 rpm. for 31.4-inch pipe. Enamel is applied to the pipe by pouring from a bucket with a flat spout, and is spread by a canvas pad held against the pipe as the stream of enamel strikes it (figure 9). The two men, one pouring and one holding the pad, move along the length of the pipe applying a spiral of enamel. When the length of the pipe is completed, the direction of revolution is reversed and a second coat is applied in the same manner. To speed up completion of this operation, two pair of men work, one starting at the center of the pipe and the other at an end. The pipe is again cooled with water

and then discharged by hydraulic jacks. The minimum thickness of the enamel on the outside is about 0.09 inch. This coating averages 0.70 pound per square foot.

Each operation receives visual inspection when completed, but after coating the outside, a very thorough search is made for flaws in the enamel. The method and equipment used is described later.

The final operation is applying whitewash to the outside of the pipe to reflect the heat of the sun. This is applied by hand with long-handled mopping daubers. Space is provided beyond the outside enameling rig for the storage of 28 pieces of 31.4-inch pipe.

Figure 11 shows primed pipe in the foreground, and whitewashed pipe on the end of the line, with enameling operation between.

BLASTING EQUIPMENT

Compressed air for blasting and other uses is obtained from the steam-driven air compressor in the pump house situated in the corner of the yard. The compressor was originally provided for the operation of several air lift wells that are not at present being pumped. A 4-inch air main 400 feet long was laid, terminating at a receiver of 150 cubic feet capacity. The air consumption for all purposes ran about 8,200 cubic feet of free air per length of pipe, or $16\frac{1}{2}$ cubic feet per square foot of surface cleaned.

The blasting equipment (figures 6 and 12) consists of two continuous feeding machines, grit hoppers, and grit elevator, in addition to equipment already described. Each feeding machine is built in three compartments, the lower of which is always under pressure while operating, the middle is under pressure while transferring grit to the lower, and the upper stores grit to feed into the middle compartment. An electric-motor driven cam shaft on each machine operates valves that automatically control air pressures in the two lower compartments to effect the transfer of grit and permit continuous blasting. The two continuous feeding machines stand side by side in positions so that one operator finds the valve levers convenient. Above on an independent tower is the elevator dump, screen, and receiving hopper. The receiving hopper has two outlets, one to each blasting machine, controlled by slide gates.

The elevator buckets are mounted on a chain and run at 150 feet per minute, driven by a one horse power electric motor, giving a capacity of 1,000 pounds of grit per minute. The elevator is operated less than half of the time. The elevator is inclined from the vertical

FIG. 10. THE MIRROR SMOOTH ENAMEL COATING IS CLEARLY SHOWN IN THIS PIPE BEING LOWERED INTO THE DITCH

FIG. 11. GENERAL VIEW OF LINE

about 20° and is fully enclosed. Grit is dumped from the buckets in turning over the top sprocket, and falls onto an inclined screen having 8 meshes per inch. Any material too large for the blasting nozzles is retained and the grit falls through to be distributed to the two blasting machines. The boot of the elevator is about five feet below grade and is fed through a slide gate from the concrete hopper that is built into the floor.

The track over 60 feet long on which the pipe carriage travels is embedded in a concrete floor. There is a high curb entirely around this floor and a low curb around the grit hopper mentioned above. This hopper extends from the side across under one rail to a little beyond the center of the track where it receives the grit that is dumped from the inside of the pipe. The outside blasting hood constantly discharges the grit to the sub-grade hopper.

Approximately 2,000 pounds of steel grit were discharged in cleaning the 30 foot section, equally divided between the inside and outside. This grit is then re-circulated, the system holding about enough grit for cleaning three sections of pipe. New steel grit is added daily to make up for the loss of dust. This amounted to 3 pounds per 30 foot section of 31.4-inch pipe, equivalent to 6 pounds per 1,000 square feet of surface blasted.

Dust from the outside blasting that is fine enough is lost through the vent on top of the hood. From the inside hopper the air is exhausted by a fan drawing through the boom that supports this hopper and through a cyclone separator. Dust that passes through the separator is lost and that collected is put back into the system. It has been found that very fine particles of the grit can do effective cleaning, and that particles larger than size 50 are heavy enough to stick in the steel plate when driven by the blast.

The pipe carriage for the blasting operation in the foreground of figure 12 consists of a structural steel frame on small flanged wheels propelled by a small air hoist engine capable of about 7½ hp. This engine is reversible simply by reversing the direction of air flow so the pressure and exhaust pipes are both led to the valves before the operator. Hose trailed back and forth by the carriage furnishes flexible connections. An arrangement of bypass and needle valve gives fast travel for carrying the pipe across to starting position and slow travel in the opposite direction for blasting.

Mounted on this steel chassis are four rubber tired wheels 14-inch diameter by 6-inch face, carried on elaborate dust-tight self-aligning

roller bearings. Two of these wheels are driven by a large air drill used as a motor and capable of developing about 4 hp.

The rotational speed of the pipe was about 24 rpm. for the 31.4-inch pipe. This is a surface speed of 200 feet per minute. This speed varies somewhat with the condition of the plate being blasted and the fineness of the grit, and is easily controlled by the operator through his control of the air motors. The path blasted by the four nozzles being used is 3 inches wide and the transverse speed of the carriage must be such as to travel this distance in one revolution of

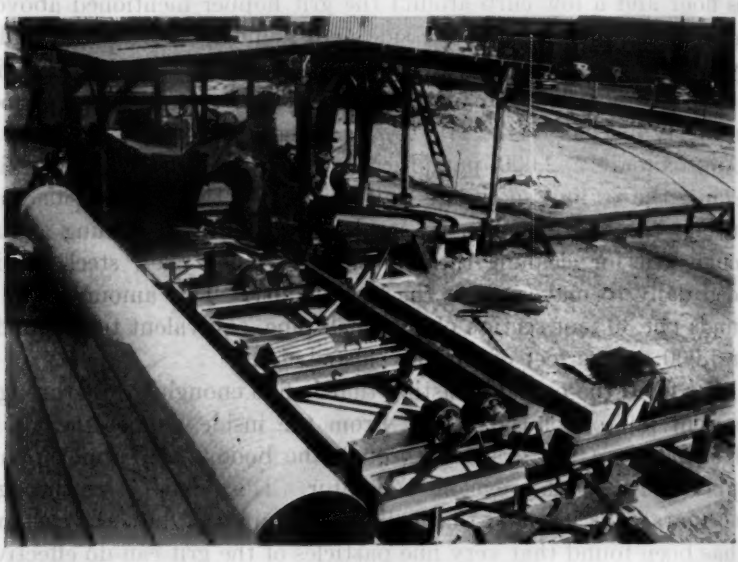

FIG. 12. BLASTING CARRIAGE AND RUNWAYS

the pipe so this travel speed must be varied in proportion to changes in the rotational speed.

The blasting nozzles are each fed by a separate hose, the dividing of the blasting mixture being done very close to each machine. Three $\frac{3}{8}$-inch nozzles were at first used on both inside and outside of the pipe, but it was soon found that batteries of four nozzles could be handled by the machines with considerable increase in speed. The actual blasting of the 30 foot length of 31.4-inch pipe was completed in 6 minutes. The handling of the pipe and emptying of the inside hopper of grit required 2 minutes, making the total time for the operation 8 minutes.

Two laborers are kept busy advancing the pipe toward the blasting machine and cleaning oil and grease off the pipe. This cleaning is very important, and must be done with a coal tar solvent. The air valves controlling the blasting machines are handled by a skilled mechanic, and two laborers are required to dump the inside hopper, tend to the flow of grit to and from the grit elevator, and between times sweep up.

Two men are kept busy cleaning the dust from the inside of the pipe and applying the primer to the inside, while one man sprays the primer on the outside of the pipe.

INSIDE ENAMELING MACHINE

The inside enameling machine, figure 8, is driven by a gasoline engine with automobile transmission and clutch because of the speed variations and acceleration possible with such a unit. The actual power requirements could be met, it is estimated, with about $7\frac{1}{2}$ hp. in an electric motor with its high starting torque, but the speed variation desired on this equipment could not be reasonably obtained in an electric motor.

The pipe rests on rubber tired rollers 10 inches diameter by 6 inches face running on taper roller bearings. At one end are a pair of idling rollers mounted on a steel frame on a concrete foundation, one roller being movable to give different spacing for pipe of different diameters. The driving rollers 26 feet away are also carried by a steel frame and concrete foundation with one adjustable for spacing. They are both driven through bevel gears, the lay shaft passing across the ends of the roller shafts. The movable roller block also carries the bearing and thrust for the bevel pinion which slides on the lay shaft with a feather key to drive it. Automobile rear axle bevels and pinions were used in this construction. The lay shaft is driven from the engine by four rubber V belts.

While the process of applying enamel used on the 31.4-inch pipe, and being described here, requires only that the pipe be brought up to a certain speed and held there, the process used on pipe too small to use the enamel troughs inside the pipe requires a speed variation of approximately 7 to 1 with a very fast speed to get centrifugal distribution of the enamel. In this latter process, enamel poured into each end of the standing pipe must flow to join in the center. The pipe is then turned slowly a few turns to wet the entire surface,

and finally speeded up for complete smoothing out of the enamel. Pipe of 4- to 16-inch diameter has been enameled by this process.

Four 125 gallon melting kettles are used to supply enamel for the inside. Two kettles are located on each side of the line, one being drawn from while the other is melting cold enamel. These are stationary kettles built in the Water Bureau's shops. They are well insulated and are gas fired. Each has its own gas pressure regulator and is controlled by a thermostat to supply enamel at a temperature of 490 degrees F.

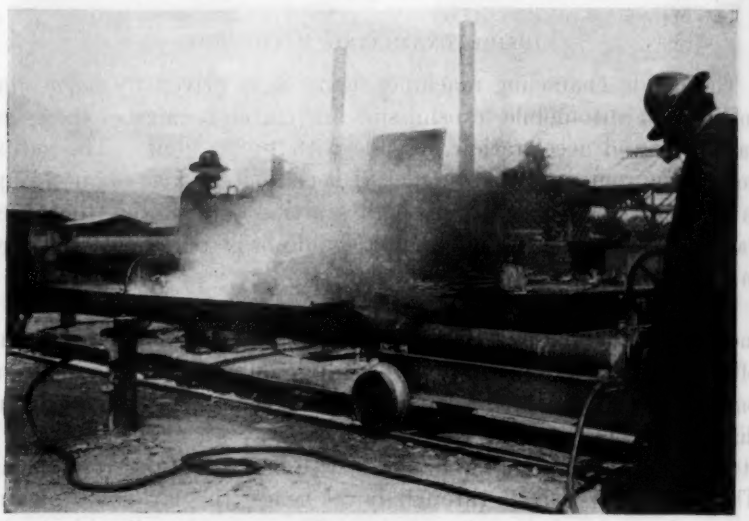

FIG. 13. ENAMEL TROUGH CANTILEVERED FROM COUNTERWEIGHTED CAR

Enamel is drawn from the kettles into the troughs mentioned before. These troughs are each 16 feet long of 90° V section 7½ inches on a side (figure 12). A dam clamped into the V gives an effective length as desired of about fifteen feet. These troughs are made of ⅛-inch steel and are mounted for rigidity in a 6-inch standard pipe from the top side of which a strip has been cut. The pouring edge of the trough must be extremely straight and frequent truing up is necessary. The 6-inch pipe boom supporting the trough is about four feet longer than the trough, the extension being used to mount the assembly on a counterweighted car running on a track carefully lined up and leveled. The troughs are insulated with over

a half inch of asbestos and are electrically heated. Each trough is provided with 4,000 watts of strip heating elements. The first heating elements used were short-lived, the insulation breaking down under the temperature at which the enamel is used. We were finally able to get encased elements of the "Calrod" type in straight strips. If the troughs are not heated they must be scraped thoroughly immediately after each pouring or the enamel will congeal and build up on the trough. Partial heating is bad also, as the lumps of enamel will come off with the next pour.

The entire operation of coating the inside of a section of pipe required 5 minutes.

The inside enameling operation requires two laborers to advance and straighten the pipe on the runways, two laborers to tend the melting kettles, a man on each of the enamel troughs, and a mechanic handling the drive controls and in charge of this operation. Timing of all steps, from the filling of the troughs with enamel to the cooling of the pipe with water, is important in this operation, and is signaled by the mechanic in charge.

OUTSIDE ENAMELING MACHINE

For enameling the outside of the pipe (figure 9), it was found necessary to use steel rollers at this time. The pipe being processed had formed bells and spigots for cement joints and these irregular shaped ends cut rubber tires severely. The rollers for the outside coating are spaced to contact the extreme ends of the pipe since it is not desirable to apply enamel there until after the pipe is laid. In this case if pipe of shorter length was to be handled, the idling rollers would have to be moved. These rollers are also adjustable for various diameters of pipe.

The drive of the outside rolling rig is by a 5 horsepower electric motor. Transmission from the motor speed of about 1420 rpm. to the roller speed of 55 rpm. is by roller chains and Llewellyn variable speed drive. The variable speed drive was used for changes of speed while experimenting to find the best speed, and later was left in position to give a surface speed of the pipe of 165 feet per minute. Both rollers on the driven end are driven, but the traction on the steel wheels is poor and slipping takes place while accelerating the pipe. Since the process requires reversing the direction of rotation, the three phase motor is particularly adapted to this drive.

The time required for making the two passes on the outside of

the pipe using two pads simultaneously was 8 minutes. This time could be cut a little by using pads in three positions along the pipe.

The outside enameling is completed by two pourers and two pad men. Assisting these are one kettleman and two laborers.

The enamel is melted in two kettles of 125 gallon capacity. The hot enamel is drawn directly into the pouring pails that have a capacity of 3 gallons. The pails were made in the Water Bureau's shops from sheet steel, with all joints welded. The flat spout delivers a stream of enamel 3 inches wide directly on to the surface of the pipe.

The enamel is imediately spread by the canvas and asbestos pad held and guided by hand. The control of the pad to produce a reasonably smooth and uniform coating requires considerable skill and practice.

Enamel for the outside and inside coatings is used very fast, and must be broken into pieces of not over about five pounds for charging into the kettles. This work was done by two laborers and a mechanic who go on duty at midnight to break out enamel for the next days work. The enamel is received in thin steel drums about 600 pounds each. The steel drum is ripped open and the enamel broken up with axes. About 30 drums were required for the average days run.

RUNWAYS

The runways consist of 4 x 6 timbers mounted on concrete piers. The piers are spaced 4 feet along the runway and have anchor bolts cast in the top. A strip of steel attached to the top of the 4 x 6 provides a hard rolling surface of very narrow width. Two kinds of steel shapes were tried for this purpose in different sections of runway. Round steel 13/16-inch diameter and one inch channel, legs up, are in use. The channel section has proven best for this purpose. The runways are spaced 20 feet apart and are very carefully leveled. Beyond the outside enameling machine, there is no steel rail on the runways, but rubber padding is used to avoid damage to the enamel. Old fire hose was split into two strips to provide this padding. The pipe is easily rolled on these runways, but it is impossible to keep it going perfectly straight. Therefore before each machine is reached means are provided for moving the pipe longitudinally to the proper position.

A pair of rollers 3 inches in diameter and 12 inches long were placed parallel to the runway, one close to each runway. These rollers were placed with the top slightly above the runway so that they

take the weight of the pipe. A ratchet wrench is attached to the shaft of the rollers, so that by turning the roller the pipe is moved longitudinally, and lined up for the next operation.

INSPECTION OF COATING

Extremely thorough inspection of every square inch of enamel is accomplished by the use of high voltage electricity. The enamel is an excellent dielectric, and this property is taken advantage of. A voltage of about 15,000 is impressed on the film of enamel by means of flat brushes of fine steel wire. This high tension seeks out every

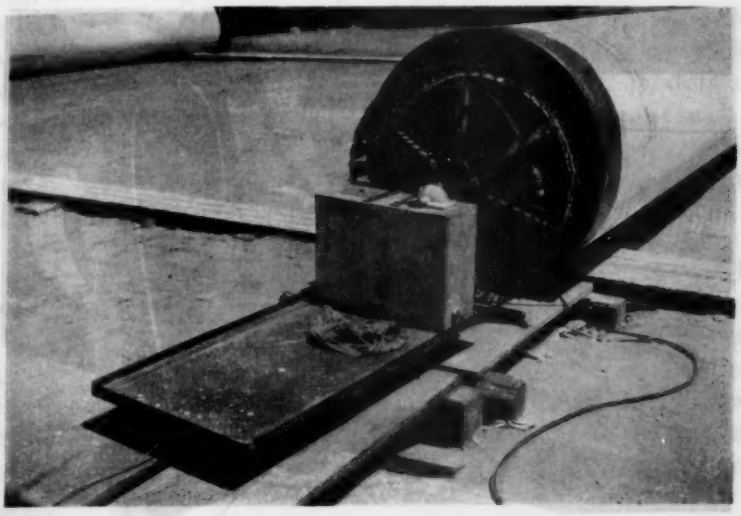

FIG. 14. INSIDE HOLIDAY DETECTOR

flaw. Bubbles, cracks, and thin spots that cannot be seen are quickly indicated by the flash and crackle of the spark. The voltage used will puncture a film of enamel less than about 0.04 inch thick such as might conceal a bubble. All places where the spark flashes are marked, and hot enamel is applied to them by hand.

A small transformer with suitable secondary voltage is used in this inspection apparatus. For the inside of the pipe, a small car on rubber wheels (figure 14) carries the transformer, and a circular detector brush that sweeps the entire circumference of the pipe. One terminal of the transformer secondary is connected back to the grounded side of the line and a lead from this is clipped to the pipe.

The other secondary terminal is brought to the wire brush. The inspector pushes the car ahead of him through the pipe, with the 110 volt cable trailing. The brushes sweep the entire surface, making necessary only one passage through the pipe. The circular brush is built in segments, and these are movable through an umbrella-like arrangement so that the brush can be collapsed by the operator at any time that he wishes to back up a little.

For detecting flaws in the enamel on the outside of the pipe, the wire brush is manipulated by hand, the current being supplied through a long automobile spark plug wire (figure 15). The brush

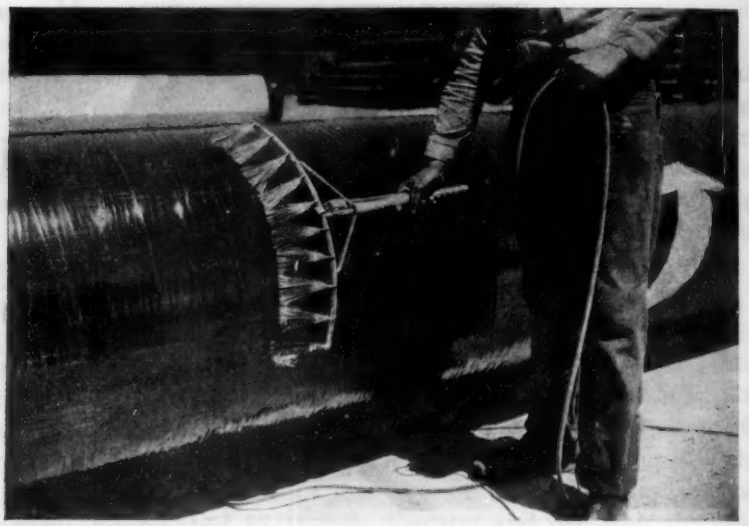

FIG. 15. INSPECTION OF OUTSIDE OF PIPE

is curved to engage about a sixth of the circumference of the pipe, and the pipe is rolled along to give access to the entire circumference.

Places marked by the inspector are daubed by hand with hot enamel, and the high voltage again applied. To retain the perfection of the coating, similar spark testing is carried out in the ditch after installation of the pipe. Automobile vibrator spark coils and storage batteries are used there.

Inspection of the enamel coating is made by two men handling the electric spark testers. One laborer assists in handling the pipe and daubs the few defects found.

Whitewash is applied to the outside of the pipe by one laborer to complete the pipe ready to be loaded on the trucks for hauling to the job. This makes the personnel required to operate the plant a foreman, 3 skilled mechanics in the key positions, 24 common laborers, and 2 inspectors.

SAFETY AND HEALTH

The men working around the blasting equipment all wear dust respirators to avoid inhalation of the dust from this operation.

All men working around the priming and enameling stations must take unusual precaution for protection from the fumes of the coal tar. These fumes are very irritating, producing an effect on the skin like sunburn. Cartridge type smoke and fume respirators are worn by all the men. All bare skin on the arms, face, or neck is protected by the application of a heavy coat of anhydrous lanolin. Goggles protect the eyes from fumes, and are fitted with tinted glass since the glare of the bright sun on the shiny coatings was found to produce considerable eye strain.

An artificial breeze is produced by blowers to drive the smoke away from the men as quickly as possible.

The speed of rotation of the pipe while being coated on the inside causes considerable bouncing of irregular pipe while accelerating, and steel guards are placed over the pipe to prevent its being thrown off the rollers. Pipes are blocked on the runways to prevent unexpected rolling, and men do not go between the runways unnecessarily.

Materials used for the pipe coating are inspected prior to use, and samples from the kettles are tested under the direction of Harry Hayes in the Field Engineering Laboratory. The plant was constructed and operated under Thomas Brooks, Superintendent of the Distribution Construction and Operation Division of the Bureau of Water Works and Supply of the City of Los Angeles. The general layout, construction, and subsequent operation was directly supervised by Fred Brooks, foreman, while mechanical details were designed by Howard Waite, under the supervision of the writer. E. W. Breitkreutz, assistant engineer to Thomas Brooks, and L. A. Ghiotto, Superintendent of Construction, gave valuable assistance in the construction of this plant.

STANDARD SPECIFICATIONS

Appended hereto is a copy of Standard Specifications for the application of coal tar enamel which are in current use with the Bureau. While they deal particularly with the centrifugal casting method of application, they may be with slight changes adapted to any other type of application. These specifications represent the present practice of the Bureau in coating application, and whether the work is done by contract or force account, are strictly adhered to. They are included here as an illustration of how coal tar enamel and primer should be handled to produce the maximum benefit as a protective coating.

APPENDIX—BUREAU OF WATER WORKS AND SUPPLY STANDARD SPECIFICATION NO. 11

DETAILED SPECIFICATIONS FOR APPLICATION OF PIPE COATING

General

The Contractor shall furnish all labor, equipment and material required and shall prepare all surfaces to be coated, and shall apply coal tar primer and the coal tar enamel to all interior and exterior surfaces to be coated, in the manner hereinafter specified.

Cost of all work described in this section shall be included in the bid prices for coating steel pipe and specials.

The entire operation of priming the pipe and heating and applying the enamel coatings shall be performed by experienced men, skilled in the application of high melting-point coal tar enamel, and shall be subject to the approval of the Engineer.

Preparation of surfaces

(A) *Cleaning.*

Before sand-blasting, all oil and grease on the surfaces of the metal shall be removed thoroughly by flushing and wiping, using 'XYLOL" or other suitable coal tar base solvents, and clean rags. The use of dirty or oily rags or solvent will not be permitted.

All other foreign matter shall be removed by buffing or by scraping and wire-brushing.

(B) *Sand or steel grit blasting.*

All metal surfaces to be coated shall be thoroughly sandblasted to bright metal in a manner satisfactory to the Engineer.

At the option of the Contractor, steel grit blasting may be employed as an alternate to sandblasting, in which case No. 50 or No. 60 steel grit shall be used. (All reference to sandblasting in these specifications shall be construed as either sandblasting or steel grit blasting.)

Sandblasted surfaces which rust before a priming coat has been applied shall be cleaned of all rust by buffing or wire brushing, or, at the discretion of the Engineer, shall be re-sandblasted.

Adequate air separators shall be used to effectively remove all oil and free moisture from the air supply to the sandblaster.

Priming

All steel surfaces, before priming, shall be thoroughly cleaned of dust and grit by brushing and air-blowing.

(A) The primer to be used shall be as specified under "Primer Specifications."

(B) All steel surfaces shall be primed immediately following sandblasting and cleaning.

(C) The surfaces to be primed shall be absolutely dry at the time the coating is applied and no primer shall be applied during rain or fog unless protected from the weather by suitable housing.

(D) The application of primer shall be by the air-spray-gun method, and shall be in accordance with instructions for application as supplied by the manufacturer of the primer.

The spray-gun apparatus to be used for application of the primer will be required to meet the approval of the Engineer, and shall include:

(1) A mechanically agitated pressure-pot.

(2) An air separator that will effectively remove all oil and free moisture from the air supply.

(E) The priming coat after application shall be uniform, free from floods, runs, sags, drips, holidays or bare spots. Any bare spots or holidays shall be recoated with an additional light application of primer. All runs, sags, floods or drips shall be removed by scraping and cleaning and the cleaned area retouched or, at the discretion of the Engineer, all such defects shall be remedied by sandblasting and repriming. Excessive accumulation of primer in pit holes in pipe will not be tolerated.

If primer coat is applied during cold weather, the primer shall be heated and maintained at a temperature of not less than 100°F.

during spraying operation. If necessary the steel to be primed shall be preheated to obtain a smooth, even coating of primer free from wrinkles or crawls.

Under no circumstance will the use of thinner in the primer be permitted.

(F) The primer shall be allowed to dry for a minimum of 24 hours or a maximum of 72 hours between the application of the primer coat and the enamel coat.

Suitable measures shall be taken to protect applied primer from contact with rain, fog, mist, spray, dust or any other foreign matter, until completely hardened.

If the enamel is not applied within 72 hours after priming, the pipe shall be reprimed with an additional light coat of primer or, at the discretion of the Engineer, the entire prime coat shall be removed by sandblasting and the pipe reprimed.

Enamel application

(A) The enamel to be used shall be as specified under "Enamel Specifications."

(B) *Heating of enamel.*

1. The enamel shall be heated in approved batch-type tar pots, equipped with accurate and easily read thermometers. In addition the Department reserves the right, at the discretion of the Engineer, to provide recording thermometers, said thermometers to be installed on the tar pots as directed by the Engineer and at the expense of the Contractor.

Such thermometers shall not be tampered with by others than the Engineer. The charts therefrom shall constitute a basis for acceptance or rejection of any enamel coating.

2. Tar pots shall be supplied in sufficient numbers so that the enamel may be heated in batches and so coördinated in individual capacity with the application procedure that no enamel shall be held in the tar pots at application temperatures for longer periods than 1½ hours.

Tar pots shall not be permitted to act as continuous source of supply by adding unmelted enamel during the time they are in use but shall be completely emptied of one charge and cleaned, if necessary, before the next charge of unmelted enamel is added.

Tar pots shall be covered with hinged lids which may be securely fastened down.

3. The enamel shall be maintained moisture and dirt free at all time prior to and at the time of heating and application.

4. In loading the tar pots the enamel shall be broken up into small pieces, none to exceed approximately twenty pounds.

5. In heating the enamel, the charge shall be melted and brought up to application temperature as rapidly as possible without injury to the enamel.

The temperature at which the enamel will be applied shall be in accordance with recommendations furnished by the manufacturer of the enamel.

The hot enamel shall be thoroughly stirred at intervals not exceeding fifteen minutes apart, regardless of whether the enamel is being used from pots or is being held ready for use. Iron paddles shall be used for stirring; wooden paddles will not be permitted.

6. The maximum allowable temperature to which the enamel may be heated shall not exceed the manufacturer's recommended application temperature by more than 25°F., nor shall the enamel be applied at a temperature lower than 25°F. below said application temperature.

Enamel that has been heated in excess of temperature herein specified or enamel that has been held at application temperature for a period in excess of 1½ hours shall be condemned, dumped and considered as waste material to be paid for by the Contractor.

7. Fluxing the enamel will not be permitted.

8. Excess enamel remaining in a pot at the end of any heat shall not be included in a fresh batch in an amount greater than 10 per cent of said batch.

9. Tar pots shall be emptied and thoroughly cleaned at the end of each eight-hour shift. The material removed in cleaning the pots shall be dumped and wasted, except material as may be permitted to be saved by the Inspector. This paragraph shall apply regardless of the number of shifts per day.

(C) *Application of enamel.*

1. The surface to be enameled shall be absolutely dry and clean at the time the coating is applied. No enamel is to be applied during rain or fog unless protected by suitable housing.

Any damage occurring to the primer coat shall be retouched before application of the enamel.

2. The application of the enamel to the inside surface of all pipe other than specials shall be by the centrifugal casting method.

a. Pouring trough extending the entire length of the pipe in either one or two sections shall be used. Electrically heated pouring troughs are recommended.

b. Hot enamel shall not be held in the pouring troughs between filling and pouring, for a length of time exceeding one minute.

c. During the application of the enamel the pipe shall be revolved at such speed as best suited to produce a smooth, glossy lining of the proper thickness.

Placing the molten enamel on the bottom of the pipe and then rotating the pipe will under no circumstance be permitted.

d. Excess enamel remaining in the pouring trough shall be removed by scraping after each pour, or at frequent intervals as directed by the Engineer. The enamel thus removed may be re-used if added to fresh batches in small percentages, provided it is free of dirt and other foreign matter.

e. The finished coating shall be of uniform thickness, free from wrinkles, sags, blisters or blow holes.

The thickness of the coating shall be 0.125 inches; allowable variations in thickness shall not exceed plus or minus 0.030 inches.

f. If particles of free carbon or other deleterious materials appear in the finished coating, all such material shall be removed and the coating repaired. At his discretion, the Engineer may require the hot enamel to be screened.

g. Water for the cooling shall not be applied to the coating inside the pipe until the enamel has hardened sufficiently to prevent water marks.

Water shall not be applied to the exterior surface of the pipe to aid cooling, unless otherwise directed by the Engineer.

h. The pipe shall be enameled over the entire interior surface except that portion of ends which shall remain bare in accordance with instructions from the Engineer.

i. Inasmuch as the carrying capacity of the pipe line is dependent on the smoothness of the lining, all pieces of lined pipe in which excessive brush marks appear or other irregularities exist, or which are otherwise unsatisfactory to the Engineer, shall be stripped of the entire lining by a satisfactory method and relined as herein required for original lining.

3. The application of enamel to the exterior surface of the pipe shall be by hand-daubing or by pouring and wiping or by other approved methods.

The finished coat of enamel shall be glossy, continuous, free from defects such as blisters, pin holes, bubbles, and festoons, coated to uniform distribution and thickness, tightly bonded to the priming coat.

a. The thickness of the finished coat shall be 0.100 inches; allowable variations in thickness shall not exceed minus 0.020 inches.

b. The pipe shall be enameled over the entire exterior surface except that portion of ends which shall remain bare in accordance with instructions from the Engineer.

c. The enameled pipe shall not be rolled or supported on its enameled surface until thoroughly cooled and hardened.

4. All specials which cannot be coated by centrifugal casting shall be coated by hand-daubing. Brushing shall be by double lap or "Shingling" method with brush strokes parallel with the axis of the pipe.

Inspection

Before final acceptance of the Enamel Coating, the entire interior and exterior surfaces of all coated pipe will be inspected by the Engineer and tested for defects by means of an electrical flaw detector or any other methods he may deem advisable, and all defects found shall be repaired satisfactorily by and at the expense of the Contractor.

Whitewashing of coated pipe

The outside enamel surfaces of all pipe and specials shall be given a coat of whitewash immediately following a satisfactory outside electrical inspection. The whitewash shall consist of a mixture of quick lime, water, salt, and a vegetable oil plasticizer which shall be furnished and applied by and at the expense of the Contractor, and shall be subject to the approval of the Engineer.

Transportation and handling of coated pipe

At all times during handling, transportation and storage, effective measures shall be taken to preserve the enamel coating intact. Any skids or ramps used shall be suitably padded. In storage, coated pieces shall be securely held in place by padded wedges or bumpers. In transportation, the enameled pipe shall be supported on the trucks on wooden timbers 12 inches in width, hollowed out on the supporting surface to fit the curvature of the pipe and suitably padded.

Not more than five pipes, nor more than two layers of pipe shall be contained in any one load. In hoisting, pipes or specials shall be suspended from wide canvas or other suitable slings; chains or ropes shall not be placed in contact with the enamel coating. Metal bars, narrow skids, tongs, cables or any other implements likely to cause injury or abrasion to the coating shall not be used. All handling or hauling equipment and all methods of handling shall be subject to the Engineer's approval.

Should any damage to any of the coating occur at any time, the area affected shall be immediately prepared and re-coated as herein prescribed for the original covering. It is the intent of these specifications that the Contractor shall take adequate measures to prevent any damage to the coating until final acceptance of the work.

Laying of pipe

(A) The pipe shall be stored along the trench side, supported on 4″ x 4″ wooden timbers, placed under the uncoated ends of the pipe. Any necessary rolling of the pipe shall be on these timbers. At no time will the pipe be permitted to rest or roll on its coated surface.

(B) The pipe shall be hoisted from the trench side to the trench by means of a wide canvas or leather sling; chains, cables, tongs or other equipment likely to cause injury to the enamel coating, or dragging or skidding the pipe, will not be permitted.

(C) Where the trench traverses rocky ground or ground containing hard objects that might penetrate the protective coating, a layer of screened earth or sand, not less than three inches in thickness, shall be placed in the bottom of the trench prior to installation of the pipe.

(D) The Contractor shall, at all times during the erection of the pipe line, use every precaution to prevent injury to the protective coating on the pipe. No metal tools or heavy objects shall be unnecessarily permitted to come in contact with the finished coating. Workmen shall be permitted to walk upon the coating only when necessary, and in case of such necessity the workmen shall wear shoes with rubber or composition soles and heels.

Any injury to the protective coating, from any cause, during the erection of the pipe line, before final acceptance by the Department, shall be repaired as directed by the Engineer, by and at the expense of the Contractor.

(E) After completion of the assembly of the field joint, the joint shall be given a protective coating of enamel by and at the expense of the Contractor, which shall meet the approval of the Engineer. All exposed steel surfaces about the joint shall be thoroughly cleaned, primed and enameled. The primer shall be allowed to dry a minimum of twenty-four (24) hours before the enamel is applied. The minimum thickness of the enamel shall be 0.100 inch. The enamel used shall be the same material as used for coating and lining the pipe.

(F) All field coating work will be thoroughly inspected by the Engineer, using an electrical flaw Detector, and any flaws or holidays found shall be repaired by the Contractor.

(G) After final inspection, all field applied enamel shall be given a coat of whitewash, by and at the expense of the Contractor. The whitewash shall be of the same composition as that used for coating the enameled pipe. Backfilling about the enameled and whitewashed joints or any other part of the pipe that is whitewashed in the field, before the whitewash is thoroughly dry, will not be permitted.

(H) Back filling shall be conducted at all times in such a manner as to prevent injury and abrasion to the enamel coating of the pipe. Rocks, clods, and other hard objects will not be permitted to fall upon the exposed pipe.

In the event that rocks or other hard objects occur in the back fill along any section of the pipe line, such back fill shall be screened before being placed about the pipe; or, at the option of the Contractor, suitable waste back fill from other parts of the line may be transported to and placed about the pipe in such sections.

Settlement of the back fill in the trench shall be by means of flooding and puddling. Tamping, jetting or rodding with metal rods will not be permitted.

REPORT OF THE GENERAL POLICY COMMITTEE[1]

To the Members of the American Water Works Association.

On March 29, 1936 the American Water Works Association completed its 55th year of existence. During its history it has made several important policy changes. During the years 1912–1914 an intensive study of its activities was made and it will be remembered that from a "one convention a year," "one volume per year," organization the change was made to an international-sectional basis and the JOURNAL was started. We are all aware of the way in which the number of sections has grown and how valuable are the section meetings. They serve not only the membership within the section area but tend to build up more effectively the "Association" viewpoint. The JOURNAL has grown from a quarterly to a monthly magazine and in its "abstracts" section affords reference material to all important water supply literature from the principal North American as well as international sources.

Again in 1924, George W. Fuller's report on "Development of the A. W. W. A." evidenced the value of a self examination by the Association of the way it was serving the field. This report set forth more clearly than had been done before the value and sphere of activity of the technical divisions. It may be noted that one division then set up—that of "Fire Protection" no longer exists and that the present "Finance and Accounting" division was not mentioned. At that time (1924) the first Edition of the Manual of Water Works Practice was in preparation. The Standardization Council was shortly thereafter superseded by the "Committee on Water Works Practice" and the latter group continues to organize and make effective the desire of Association members to contribute to the advancement of their field.

Twelve years have passed since a definitely organized study has been made of the scope and policy of the organization. The constitution says that "the object of this Association shall be the ad-

[1] Prepared and published in accordance with resolution of Board of Directors (June 11, 1936).

vancement of the knowledge of the design, construction, operation and management of water works. . . ." It is entirely proper that the Association should attempt an evaluation of its present activities simply as a means of organizing more effectively for progress.

Its definite and clear field relates to urban water supply. Geographically its membership centers in the United States and Canada. Urban or "public" water supply is essentially a municipal administractive service. That service may be rendered by the municipality in its corporate capacity or it may be rendered by a privately owned concern. The distinction between types of ownership is not important to the Association. The point of importance at this moment is that the field from which our membership is drawn is basically that body of persons engaged in a "service" activity in their own communities. Drawn into the organization by the nature of their affiliated interests are on the one hand engineers—civil, mechanical and chemical, public health executives, and on the other hand those manufacturers and their representatives engaged in the production and sale of water works equipment, all of whom desire to improve the character of public water supply service. Of those directly in municipal service plants every category of employee—superintendent or manager, division superintendent, chemist, bacteriologist, accountant and engineer etc. finds a place in the Association.

While there is no desire to minimize the importance of the contributions which the engineers and technicians have made to the Association and while it is definitely hoped that such contributions will continue, it is proper to point out that the American Water Works Association is not an engineering organization. Water works practice must keep abreast of advances in engineering knowledge, but if it fills its peculiar and definitely indicated place in the category of voluntary associations, it must increase its emphasis upon public or municipal service and its staff must set up contacts with organizations serving the affiliated fields of service.

When our headquarters were moved to New York, they were located, after an interval, in the Engineering Societies building and the possibility of staff contacts with the engineering groups thus provided. The contacts thus made possible do not seem to have been as close and effective as might be desired. A more important observation is that they are not with the type of organization such as the National Municipal League and others particularly dedicated to the improvement of service conditions, coöperation with which would most

promote the Association's standing and influence in the municipal field.

A digression to amplify this fact is important. In the United States there are today something less than 12000 communities having a public water supply. It appears that about two-thirds of the communities or eighty percent of the population served are served by municipally owned plants. The staffs in these plants are subject to whatever is good or whatever is evil in American municipal practice. Even the privately owned and operated plants suffer under bad or inefficient municipal administration and find their problems lessened if the municipal administration is good. Tenure of office in municipally owned water plants is subject to all the evils of the spoils system. Eighty percent of the employees of the water department in one of the largest U. S. cities were displaced two years ago—frankly and admittedly as a part of the spoils of a political change. All students of government in the U. S. from Lord Bryce to the present day, admit that the great failure of the American democracy is the government of its cities. The country has steeped itself in a tradition that administrative or technical services as well as purely governmental services do not demand training and tenure for efficiency. But every political scientist knows that if that idea has any validity, it does not extend to the personnel of the cities technical services. There, if the real values of city life are to be achieved, a definite recognition of the value of training and experience must govern the control of personnel.

With the addition of the New Jersey Section the Association now has twenty one sections, covering all of the Dominion of Canada and the United States. Sections are of various sizes ranging from ten limited to one state to one covering all or part of five states and two six States. The Canadian Section includes the entire Dominion. There are many factors affecting the activity or character of a section. Some of the factors center about the relationships with State Sanitary Engineers. Some sections seem to suffer for lack of guidance or suggestions as to program building; nearly all evidence the need of a centrally directed membership recruiting policy.

At the time of the January, 1935, Directors meeting in New York, a discussion relative to the formation of a New Jersey Section indicated that the Association lacked a definite program as to the development of additional sections. The President of the Association was authorized to set up a committee to study the matter.

Consideration of appointment of the committee personnel led to the opinion that the study of section development was so greatly involved with a number of other matters that the scope of activities should be enlarged to take in a number of related questions. Therefore the Board of Directors by letter ballot, unanimously authorized the committee to study:

(a) The proper field and extent of A. W. W. A. activities and the manner in which the Association is now meeting the needs of the field;

(b) The geographic limits of the various sections and possible readjustment thereof;

(c) The number and extent of activities of various State Water Works Schools and Operators conferences;

(d) The manner and extent of coöperation between such groups and this organization;

(e) The extent of participation of this Association in research projects, both inter and intra-Association;

(f) The possibility of increasing the collection of water works statistics by the Association's office staff:

(g) The growth and distribution of Association membership by classes and consideration of possible means of increasing it upon a stable basis.

The committee was given the name "General Policy Committee" and to it were appointed Messrs. Barbour, Dobbin, Fenkell, Pirnie, Pracy, O'Brien and Jordan (as chairman). A memorandum (dated March 25, 1935) was commented upon by the members of the committee. A second memorandum went to them on April 30 and during the Cincinnati convention they held a number of meetings. At the meeting of the Board on May 7, 1935, an informal review of progress was made, presented to the Board, and the committee was directed to continue its studies.

Further correspondence was carried on, memoranda were issued on November 11, 1935, and January 11, 1936. The committee met in New York on January 16, 1936, and its progress report with certain recommendations was made to the Board on the following day. Every member of the Board received a complete copy of this report along with the minutes of the meeting. (At this time, President-elect Hurlbut was, by action of the Board, made a member of the committee.)

During the interval between the organization of the committee

and its report to the Board on January 16, 1936, it had reached the opinion that the first question which it had to consider was of such a nature as to require solution before the other matters could be put forward upon a progressive basis. In other words, the answer which the committee reached to the question—"What is the manner in which the Association is meeting the needs of the field?" was "The Association is not adequately meeting the needs of the field and the prime reason is that our administrative staff is neither organized nor operating properly." Quoting from the report to the Board:

"Your committee recommends to you the four following expressions of policy.

(1) As a means of stabilizing the influence of this Association in water works affairs it should maintain a well planned membership expansion program.

(2) The Association should encourage the organization of more sections within single state boundaries in order to capitalize the already existing unity of interest.

(3) It should establish definite and effective contact with other organizations interested in the improvement of municipal administractive practice.

(4) The Association should set up as a major and continuous program the improvement of the status of all water works personnel.

"To make these, as well as other correlative aims effective, your committee has given much study to the present administrative staff and its performance. It is aware of the virtue of the previous administrative reorganizations, for the purposes and at the times at which they occurred. It is fully appreciative of the quality of service rendered by the staff within the field which they have considered to be their proper scene of activity.

"Your committee is fully convinced that for the future good and progress of the Association, a redefinition of administrative functions is imperative and that incidental thereto certain changes in personnel may be required. Emphasis needs to be made and activities undertaken both of which demand more active direction than our staff now receives.

"The first and major redefinition of duties relates to those of the Secretary. In addition to the constitutional and somewhat traditional duties of this office, an extension is needed to the end that the Secretary become the continuous active administrative head of

the Association. Not only is it necessary that he be a resident of the headquarters city or its immediate environs, but also that he be in a position to give full time to the planning and execution of Association activities. He must be a person of demonstrated executive ability, capable of stimulating activity in the interest of the Association among all classes of members. He must be recognized as a leader by all classes of Association membership and be capable of promoting the interests of the Association among manufacturing and municipal executives. To him should be added the duty of continuous and active direction of Water Works Practice committees, subject to the advice and counsel of the Chairman of the Committee. He should be permitted to contact the members of the Association in section and national meetings fully enough to enlist the services of the newly active members in worth while Association work.

"Under him, as soon as reorganization could be made effective, should serve a Technical Assistant and a Membership and Finance Assistant. To one, in proper time, should be assigned the routine technical work in connection with water works practice and also the editorship of all the Association's publications. To the other should be assigned the membership activities and the promotion of advertising income.

"A General Secretary and two typists complete the resident office staff. The Technical Assistant would require certain additional part time service in relation to the Journal.

"The salary budget for this staff should total not much over $26,000 per year, with the Secretary receiving $10,000–$12,000 per annum for his work.

"It is the judgment of your committee that, if the Association is to keep step with the needs and opportunities of the field, such reorganization needs to be made effective as soon as it can be courteously and effectively arranged. Obviously the Association must recognize the past services of its present Secretary by an emeritus designation and a reasonable annual honorarium.

"When such changes are made, it will be possible for the Association to move definitely forward along lines of adding members, organizing additional sections and contacting other municipal organizations, all to the ultimate end of increasing the influence of this Association and giving greater stability and economic security to the men in the water works field.

"To that end, we recommend that the Board authorize this com-

mittee to set up definite assignments of duty for a staff to be organized along the lines above described, and that the committee be authorized to make any changes in staff personnel necessary to effectuate the organization above described."

This report was heard by 28 of the 29 members of the Board, a full discussion was had, Mr. Little was present throughout and, at the invitation of Mr. Barbour, presented his views. The exchange of ideas was at all times courteous and at no time did anything occur out of keeping with the dignity and standing of the Association. The minutes of the meeting (signed by the then Secretary—B. C. Little) bear the following record:

"The afternoon session of the meeting was called to order at 2:10 P.M. with President Barbour in the chair.

"Mr. Jordan, Chairman of the General Policy Committee, presented the report of this committee.

"At the suggestion of Mr. Orchard, Mr. Jordan added to the personnel of the General Policy Committee the President-Nominee of the Association, Mr. William W. Hurlbut.

"A copy of the above report of the General Policy Committee is attached to these minutes.

"Included in this report was a motion, which was seconded by Mr. Weston that

The Board authorize the General Policy Committee to set up definite assignments of duty for a staff to be organized along the lines described in the report just read and that this Committee be authorized to make any changes in staff personnel necessary to effectuate the organization above described.

"An amendment was offered by Mr. Howard, seconded by Mr. Smith that

This report be received and tabled until the June, 1936 meeting of this Board.

"This was defeated.

"Mr. Orchard offered an amendment to the above motion which was seconded by Mr. Kienle and carried, that

The General Policy Committee be instructed to carry out the intent of that paragraph of this Committee's report to the effect that the services of Mr. B. C. Little to this Association will be recognized and that he will be kept on the payroll of the Association.

"The motion as amended was then carried."

The committee continued its work and after a considerable exchange of correspondence, Mr. Barbour on April 13, 1936, put into effect the agreement of the committee. His letter to Mr. Little summarized the entire action then determined upon in the following words:

"The general Policy Committee, acting in accordance with the resolution adopted by the Board of Directors on January 16, 1936, authorizing it 'to set up definite assignments of duty for a staff to be organized along the lines described in the report just read and to make any changes in staff personnel necessary to effectuate the organization above described' has reached the following decisions:

1. That Mr. Little be relieved of all executive duties on May 1, 1936—with present salary paid to June 30, 1936, and thereafter an emeritus salary of twenty-five hundred dollars ($2500) per year.

2. That Mr. Ruggles' services be terminated May 1, 1936—with present salary paid to June 30, 1936.

3. That Mr. P. S. Wilson be employed as Technical Assistant to the Secretary to begin work on May 1, 1936, at a salary of forty-eight hundred dollars ($4800) per year, and that he be designated as 'Acting Secretary' until such time as a successor to Mr. Little is selected and ready for active duty.

4. That no change be made in Mr. Niesley's status until a new Secretary recommends it.

5. That no change be made in Mr. Wolman's status until a new Secretary is appointed.

6. That the appointment of the Secretary be deferred for the immediate present.

7. That the President of the Association notify Messrs. Little, Ruggles and Wilson of the above decisions of the committee.

"The General Policy Committee desires me to express to you its appreciation of the services you have rendered and its hope that you will continue to take an active part in the future work of the Association."

The General Policy Committee made a report of the above to the Board at the meeting on June 7 concluding with the following:

"In further compliance with your instructions, this committee will continue its work until the task assigned to it is complete."

A full and free discussion of the report was had and the Board, by unanimous vote of those present, recorded its agreement with

the action taken and the program under development by the committee. The Board further expressed its commendation of the committee for the course it had pursued.

There remain the duties of selection of a Secretary and the preparation of a schedule of duties for the various members of the reorganized staff. The latter is, to a certain degree, dependent upon the qualifications of the various appointees and needs to be deferred for the time being.

The committee is giving much thought to the selection of a Secretary. As a means of facilitating analysis of the qualities of various individuals who may be considered, the following rating outline is being used.

1. Has the man demonstrated executive and leadership qualities and has he a record of accomplishments in his past engagements?

2. Has he a record of having successfully directed employed personnel?

3. Is he at least 35 years old and is his general physical condition such as to indicate the possibility of at least 10 years service to the Association?

4. Does he have such physical appearance and personal qualities as will commend him to the men of dignity and standing with whom he comes in contact?

5. Will he be able to command the attention and respect of public officials and manufacturers in his representation of the interests of the A. W. W. A.?

6. Is the man well known in the water supply field?

7. Has he taken an active part in the voluntary activities of the A. W. W. A.?

8. Is he affiliated with other professional societies so that there is evidence of a breadth of viewpoint?

9. Is he able to make an intelligent and forceful public speech?

10. Is he able to appraise the relative importance of questions relating to water works equipment and practice?

11. Is he able to encourage and stimulate the voluntary activities of Association members in directions most productive of good to the Association?

12. Does he finally possess such a sum of qualities as to evidence his ability to encourage the membership growth of the A. W. W. A., conserve and increase its technical assets and promote the welfare of men in the water supply field?

Both your Board of Directors and the General Policy Committee are fully mindful of their present responsibilities. With good counsel and a fully intelligent appraisal of all phases of the situation, the reorganization can lead to a permanent improvement in Association activities and to the advancement of water supply practice in general.

Respectfully submitted,

F. A. BARBOUR,
R. L. DOBBIN,
G. H. FENKELL,
W. W. HURLBUT,
H. E. JORDAN,
D. F. O'BRIEN,
M. PIRNIE,
G. W. PRACY.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the journal.

Observations upon the Methods of Transmission of Amebiasis. C. F. CRAIG. Am. Jour. Pub. Health, **25**: 1231, November 1935. No new essential epidemiological or clinical data have been secured as a result of the study of the Chicago epidemic, beyond the demonstration that cross-connections may act as a very important source of infection. Some authorities have recently endeavored to prove that water is the usual agency for transmission of this parasite and that other agencies, especially food handlers, are negligible. It is desired to protest against a growing tendency to overemphasize the importance of water and to minimize what should be regarded as a much more constant method of transmission, i.e., the food handler who is excreting cysts of *E. histolytica* and who is careless in the observance of personal hygiene.—*H. E. Babbitt.*

Prospecting for Water and Testing Wells. Anon. Johnson National Well Drillers Journal, **8**: 1, 2, January–February 1936. Many thousands of dollars are lost yearly, both to well drillers and to owners, due to improper testing of wells in cases where conditions are such that proper and complete tests should be conducted. Two typical cases are described in which losses were experienced because of inadequate tests and one case is described, in which tests were made, resulting in a saving to all concerned.—*H. E. Babbitt.*

Sedimentation in Quiescent and Turbulent Basins. J. J. SLADE. Proceedings Am. Soc. Civil Engineers, **61**: 1435, December 1935. For sediment consisting of particles of constant hydraulic value in a completely turbulent basin, HAZEN'S theory is complete; but actual sediment is usually far from uniform and, therefore, HAZEN'S formulas are not always applicable. This paper develops a workable theory which takes into account the variation in hydraulic value of constituent elements of actual sediment as well as variation in degree of turbulence of the basin. Formulas obtained may be generalized to any desired degree, because of the constants in them, which fall into three classes: (1) those which represent the characteristics of the sediment; (2) those which represent the characteristics of the settling basin; and (3) those which depend on both the character of the sediment and the degree of agitation of the fluid.—*H. E. Babbitt.*

Construction and Control of Earth Dams. E. MCD. MOORE. Civil Engineering, **6**: 23, January, 1936. Description of methods used in Muskingum Valley

Flood Control Work, of local conditions encountered, and of decisions and methods based thereon. Drill holes and test pits were widely used as guides to the character of the work. Impervious sections of the embankments came from the clay-carrying earths. Equipment used in placing the material does a considerable part of the compacting. Testing of the compaction secured on these embankments is based on the weight and volume of samples taken at each dam practically every day that embankment is being placed. Probably the most difficult part of the test is the determination of volume. One of the best quick tests for an embankment is its behavior under the load of the construction equipment. There should be a visible wave as the equipment passes over it, followed by an immediate rebound.—*H. E. Babbitt.*

Soil Mechanics Applied to Design of Dams. R. R. PHILIPPE. Civil Engineering, **6**: 25, January 1936. Little attention has been paid, in the past, to knowledge of the character of soil, primarily because of lack of commercial interest in the problem. Collection of such knowledge is left to the initiative of the engineer. Because of magnitude of problem involved in studying full-size structures, study of the behavior of models has been resorted to by engineers of Muskingum Flood Control Work. Fundamental bases of the behavior and design of models are explained and methods of drawing conclusions are described.—*H. E. Babbitt.*

Measurement of Clearance for Tunnel Lining. E. L. CRANFORD. Civil Engineering, **6**: 41, January 1936. In construction of tunnels of the Colorado River Aqueduct, heading crews, in attempting to confine rock excavation to the outside limit for which payment will be made, frequently leave areas or points of tunnel wall and roof projecting for short distances inside the minimum clearance line. Before forms are set, these areas or points must be located and removed. A machine was developed for this purpose. Its construction and operation are described.—*H. E. Babbitt.*

Water Resources Problems. "State Planning": A Review of Activities and Progress. Report of National Resources Board. June, 1935. Sup't. Documents, Washington D. C. 75. Water conservation and planned water utilization have come to be regarded as of prime importance, no less in regions of natural abundance than in regions where perennial scarcity has made the wise utilization of existing resources essential to the preservation of human life. Numerous studies of water resources and problems of utilization have been prosecuted by State Planning Boards, some of which are reviewed here. Water resources have been studied in relation to all other kinds of resources. Likewise the different possible uses of water need to be studied together. The Maine studies were particularly significant. The protection of water used for municipal supplies and recreation is a pressing problem for every state. Stream pollution was reported as a serious problem by most of the State Planning Boards.—*H. E. Babbitt.*

Fifty Years of Water Works Progress. DANIEL W. MEAD. Bulletin of the Associated State Engineering Societies, **11**: 2, 12, April, 1936. We may safely

regard the development of sanitary knowledge and its application as the most radical development and improvement in water supplies in the last 50 years. This period has also seen great improvements in pumping machinery. The earlier machines were crude in design and low in efficiency. The forerunner of the modern high duty pumping engine was, it is thought, the Holly A-frame quadruplex pump that raised the duty to about one hundred million feet pounds per 1000 pounds of dry steam. The DeLaval turbo-centrifugal pump installed in Chicago in 1928 attained a duty of 218.2 million. One of the greatest improvements in water works is the organization of technical societies and the spread of information. Knowledge is one of the greatest improvements which can be noted in the water works field.—*H. E. Babbitt.*

Half a Century of Mechanical Filtration. CHAS. B. BURDICK. Bulletin of the Associated State Engineering Societies, **11**: 2, 17, April, 1936. The initial modern mechanical filtration plant was installed at Somerville, N. J., in 1885. The O. H. Jewell Filter Co. was organized in 1888 and quickly reached a prominent place in the filter business. In 1902 concrete was utilized in construction of plant at Little Falls, N. Y. Then follows list of "milestones" in the progress of mechanical filtration. The mechanical filter was developed by mechanics and was put on the market by business men; but, with expiration of the basic patents about 1910, the designing of plants was taken over by engineers, leaving to the filter companies the manufacture of special devices required.—*H. E. Babbitt.*

Development of Treatments for Eliminating Taste and Odor in Water. JOHN R. BAYLIS. Bulletin of the Associated State Engineering Societies, **11**: 2, 23, April, 1936. Charcoal first attracted attention as a means of improving the taste of water over a century ago. Sir CHAS. SINCLAIR called attention to it in 1807. Aëration was practiced as early as 1876, and probably earlier. The use of chlorine to sterilize water became common and extended rapidly after 1910, and by 1920 most water supplies subject to pollution were chlorinated. The first use of chloramine in water treatment to eliminate chlorine tastes was probably by MCAMIS at Greenville, Tenn., although the substance had previously been used for sterilization. After 1930 the use of ammonia became extensive. Activated carbons may have been produced as early as 1870, but their general use was not begun until the 1920's, although Filtchar was marketed in 1913. It is probable that there are now more than 700 plants using activated carbon for taste removal. Several other treatments have been used to eliminate tastes and odors. These include ozone, potassium permanganate, bleaching clays, etc. A lengthy bibliography concludes the article.—*H. E. Babbitt.*

Changes in Standards of Purity for Drinking Water, 1880–1935. A. M. BUSWELL. Bulletin of the Associated State Engineering Societies, **11**: 2, 31, April 1936. In 1880, the National Board of Health began an extensive study of various tests which had been proposed for detecting pollution in water. One of the earliest tests for organic matter was the effect of heat on the evaporated residue. Tests for nitrates, nitrites, chlorides, and

ammonia were in use, in substantially their present form; but the principal interest centered around the determination of carbon and of albuminoid nitrogen. MALLET attempted to correlate bacteriological examinations with the chemical data; but the methods were so cumbersome as to discourage routine examination. A facsimilie of one of the earliest chemical analysis reports, made by Prof. PALMER in August, 1896 is shown. The first standards of purity in Illinois were introduced in 1897. Bacteriological standards were attempted in 1905. The main problem which has confronted water analysts remains unsolved, namely, the detection or identification of human fecal matter.—*H. E. Babbitt.*

Back-Water and Drop-Down Curves for Uniform Channels. NAGAHO MONONOBE. Proceedings Am. Soc. Civil Engineers, 62: 5, 643, May, 1936. Most existing formulas for determining back-water and drop-down curves in open channels are applicable only to channels of simple geometric cross-section. Moreover, these formulas usually yield inaccurate results because in their derivation the effects of variation of velocity-head are neglected, or the coefficient, C, in CHEZY's mean-velocity formula is considered constant. In this study, rational back-water and drop-down formulas are derived in such a manner that they are applicable to a wide variety of commonly used cross-sections. These formulas are based on accurate mean-velocity expressions of the exponential type, and make full allowance for velocity-head effects. The results of numerous tests in experimental channels are presented and compared with values computed (1) by existing formulas and (2) by writer's new formulas.—*H. E. Babbitt.*

Surface and Sub-Surface Investigations, Quabbin Dams and Aqueduct. A Symposium. Pro. Am. Soc. Civil Engineers, 62: 3, 297, March, 1936. **Foreword.** FRANK E. WINSOR. 297. Brief history of the Metropolitan Water District of Boston, with special emphasis on the development of the Quabbin project. **Permeability Determinations.** S. M. DORE. 299. Methods for determining the permeability of an earth over-burden which forms the foundation for a proposed dam are outlined. They are based on the assumption of availability of either, or both, of two general sources of information: (1) dry samples from bore-hole investigations; and (2) effect of pumping upon ground-water conditions in that overburden. The principles involved may be adapted for use in cases where the materials are of a different nature, or where some other conditions are dissimilar. **Geologic Features, Quabbin Aqueduct.** F. E. FAHLQUIST. 329. General geology of the area, including that of the surface and that of the underground, is discussed in relation to the several practical problems encountered during the location studies. Data pertaining to the behavior of the different rocks during construction and the cost and progress of excavation through them, are also included.—*H. E. Babbitt.*

Water Supply Engineering. Progress Report of the Committee of the Sanitary Engineering Division. Pro. Am. Society of Civil Engineers, 62: 3, 355, March, 1936. Report of the noteworthy progress and trends in science and art of water supply engineering for 1935. A list and discussion of current

construction of magnitude shows the Quabbin project to have been the most costly, approximating $65,000,00. Cement-asbestos and concrete continued to be used as substitutes for cast iron and steel pipe. Effect of corrosive waters in reducing pipe line capacities has been investigated. Diesel and gasoline engines continue to be more widely used as prime movers for pumps. Outstanding developments in water treatment are improved facilities for mixing and flocculation. Unusual flood conditions have demonstrated the necessity for more complete rainfall and run-off records.—*H. E. Babbitt.*

Filtration Plants. Editorial. Chicago Tribune, April 11, 1936. The editorial is inspired by the severe epidemic of intestinal influenza experienced in Milwaukee and points to the danger which the city of Chicago faces with its dependence for protection based on chlorination alone.—*H. E. Babbitt.*

Waterworks Modernization. Anon. The Water Tower, April, 1936. A detailed description of the water works of Aurora, Illinois, stressing particularly the advantages of elevated storage.—*H. E. Babbitt.*

Typhoid Carriers. G. W. Anderson, A. D. Hamblen, and H. M. Smith. Am. Journ. of Public Health, **26**: 4, 396, April, 1936. The decline of typhoid fever, brought about by the growth of public water supplies and by improved milk and shellfish sanitation, has left a "residual typhoid" caused apparently by typhoid carriers. Water-borne typhoid and milk-borne typhoid have become so rare as to constitute an insignificant fraction of the total typhoid. Valuable information and statistics are given, which lead to the conclusions: (1) that incidence of residual typhoid is not a constant function of the total number of carriers in a community; (2) that this incidence is a function of the number of carriers produced during the preceding 5 to 10 years; and (3) that most carriers infect or immunize their immediate environment within a few years.—*H. E. Babbitt.*

Laboratory Control of Water Purification Plants. H. E. Jordan. Am. Journ. Public Health, **26**: 4, 412, April, 1936. Enough is known to build and operate purification plants so that public water supplies are seldom unsafe; but the application of that knowledge has not met all of the requirements of safety. The fault has been that of the personnel. Lack of interest that interferes with proper operation is a by-product of political control. For proper operation, the laboratory cannot be detached from the plant, for the plant is the laboratory. The paper then proceeds to discuss the significance of the standard tests and the importance of recording data. It concludes with the summary that not only are the operators controlling the plant today, but that they are engaged in research studies to aid in meeting the problems of tomorrow.—*H. E. Babbitt.*

Proposed Recommendations . . . Relating to the Eighth Edition of Standard Methods for the Examination of Water and Sewage. Am. Public Health Ass'n. Year Book, 1935–1936 page 125. Twenty-seven "fundamental" changes of considerable interest to laboratory workers are recommended.—*H. E. Babbitt.*

Administrative Control of Underground Water: Physical and Legal Aspects. H. CONKLING. Pro. Am. Soc. Civil Eng'r., 62: 4, 485, April, 1936. This paper opens a discussion of the laws relating to underground waters, the possibilities of enacting statutes for their administrative control, the form of such statutes, and the drawbacks and benefits of such control. An outline of the growth and development of water law is given, so that the foundation for the conclusions will be apparent. The paper is not a treatise on the subject. It is rather an attempt to reach a practical solution of a problem which, unlike most engineering problems, does not rest on physical laws alone, but on the laws of physics as interpreted by legal minds, and also on the fundamental law of property as applied to water.—*H. E. Babbitt.*

Transportation of Sediment in Suspension. L. G. STRAUB. Civil Engineering, 6: 5, 321, May, 1936. Although the principles underlying the transportation of sediment in suspension have been slow in yielding to mathematical analysis, considerable information of practical value on the subject has been obtained through study and research. This article outlines some of the findings of one such study, namely, the manner in which particles of various diameters distribute themselves in a vertical section; the effect of certain changes in chemical composition of the water on the mechanical composition of the suspended load; and the relation between stream discharge and the quantity of sediment in suspension. The article touches briefly on the selection of a model law, to insure similarity in laboratory studies of sedimentation basins.—*H. E. Babbitt.*

Report of Water Pollution by the Special Advisory Committee on Water Pollution, National Resources Committee, Washington, D. C., September 16, 1935. Report is one of a series of fact-finding surveys undertaken by National Resources Board. It includes sections on the Status of Water Pollution Law, The Status of Water Pollution from the Standpoint of Public Health, The Status of Water Pollution from Biological Considerations Other than those of Public Health, and the Status of Standards of Water Quality. Valuable data and information are given on each of these subjects. The report closes with a number of recommendations with special reference to water pollution. The first recommendation, however, affects the quality of available water supplies. It is to the effect that where drainage authorities exist for the comprehensive development and control of water, their scope should be made sufficiently broad to include control of pollution.—*H. E. Babbitt.*

Federal Agencies Concerned with Water Use and Control. A Bulletin issued by The National Resources Committee, January 24, 1936. Descriptions are given of the water resources activities of the following governmental agencies: Bureau of Agricultural Engineering, Bureau of Biological Survey, Bureau of Entomology and Plant Quarantine, Bureau of Plant Industry, Forest Service, Soil Conservation Service, Weather Bureau, Bureau of the Census, Bureau of Fisheries, U. S. Coast and Geodetic Survey, Bureau of Standards Nat'l Hydraulic Laboratory, Bureau of Mines, Bureau of Reclamation, Division of Grazing, National Park Service, Office of Indian Affairs, U. S. Geological

Survey, and sixteen additional governmental agencies. Each account is arranged under the subjects of Functions, Data Collected, Construction Program, and Availability of Data. A list is given of the chief offices of the agencies whose activities are mentioned in the report.—*H. E. Babbitt.*

The President's Home Town Improves Its Water Supply. JAMES C. HARDING. The American City, 50: 9, 71–72, September 1935. In 1901, Hyde Park, N. Y., built its first water supply system using Crum Elbow Creek as source. This rather antiquated system sufficed until its replacement in 1934. Same source now furnishes water to either of two 250-g.p.m. pumps, alum and chlorine being applied at the suction. Water passes under pressure through a reaction tank (which can later if desired be converted into a filter) in spiral flow, detention period of 25 minutes being allowed, and then into an 8- x 18-foot pressure filter. As taste was not completely eliminated by alum alone, activated carbon is now used in addition, with considerably more success.—*Arthur P. Miller.*

Remedies for Water Larceny. ARTHUR L. H. STREET. The American City, 50: 9, 75 and 77, September 1935. After citing several court decisions, it is concluded that safer course for water provider is to allow consumer opportunity to pay for water wasted, or wrongfully taken, before shutting off his service, rather than to discontinue service and then try to collect.—*Arthur P. Miller.*

Gloversville, N. Y., Water Supply Saved by an Economical Plan. MORRELL VROOMAN. The American City, 50: 9, 47–49, September 1935. Gloversville's gravity water supply system, built in 1877, was faced with severe water deficiency in 1930. Notwithstanding that $30,000 was spent on temporary expedients, two large consumers producing $8,000 income were lost. In 1933, owing to ground water depletion, stream flow was only one-half of that in 1930 and draft on storage was even more severe. To overcome such difficulties, a new 360-m.g. storage reservoir was constructed under CWA and TERA during a severe winter. Job included clearing 70 acres of land and brushing 35 acres. Iron, color, taste, odor, and carbon dioxide in water from new reservoir are reduced by aeration, mixture of waters, and settling, so that resulting water is clear and of good quality. A new 20-inch pipe line, paralleling old 18-inch line from old Rice Creek reservoir to the city, was constructed under a PWA contract. Certain other works to round out the system were also built. Hence, without seeking new supplies, but by amplifying and unifying existing sources, storage capacity has been increased 6-fold over that in 1930 and better water is supplied by a more flexible and easily operated system.—*Arthur P. Miller.*

Water-Works Construction with ERA Labor. FRANK A. MARSTON. The American City, 50: 9, 42, September 1935. Description of new water purification plant for the cities of Salem (pop. 43,400) and Beverly (pop. 25,000), Massachusetts, constructed by joint water supply board with ERA labor. Wenham Lake, with addition of water diverted for Longham Reservoir and from Ipswich River, supplies raw water of relatively good quality. New plant

includes mixing tanks with mechanical paddles, where alum, activated carbon, and soda ash may be added; 4 coagulation basins, providing 4 hours detention at flow rate of 8 m.g.d.; and 8 filter units, each with capacity of 1.2 m.g.d. Ammonia and chlorine can be applied either to raw or to filtered water. Lagoons are provided for settling the wash water, permitting return of effluent to the lake. Job includes necessary pumping equipment.—*Arthur P. Miller.*

Progressive Watershed Control through Planning and Zoning. M. WARREN COWLES. The American City, **50**: 10, 45–46, October, 1935. Zoning on a similar basis by state, county, and local municipality can be expected to advance watershed control over a long period through prevention. Community sanitation should be given an important place in planning studies. Planning and zoning on a broad scale will provide the basis upon which adequate watershed control can be built.—*Arthur P. Miller.*

PWA Funds for Cast Iron Pipe. JOHN T. WOODSON. The American City, **50**: 10, 55, October, 1935. As a PWA project, Lynchburg, Virginia, replaced a leaky woodstave water line with 48,000 feet of 36-inch bell-and-spigot cast iron pipe. Pipe laying afforded 300,000 man-hours of relief labor.—*Arthur P. Miller.*

Water Mains Cleaned at Woodstock, Illinois, before Softened Water Entered System. JOHN A. FULKMAN. The American City, **50**: 11, 45–46, November, 1935. Water from two gravel-packed wells has hardness of 360 p.p.m. New softening plant reduces this to 100 p.p.m. Before bringing softening plant into use, it was decided to clear the 84,083 feet of 4-, 6-, and 8-inch mains. Scraping tools of stiff sheet metal prongs were dragged, or forced by water pressure, through the pipe lines, after which the lines were disinfected with chloride of lime. Black and rusty water was eliminated and pressures and quantities increased at various points in the system.—*Arthur P. Miller.*

Ozones Solves Color, Odor, and Taste Problem in Hobart, Indiana, Plant. THEODORE O. FERKINHOFF. The American City, **50**: 11, 47–48, November, 1935. Hobart's supply, secured from Lake George, has high bacterial count and turbidity up to 1250. Treatment includes alum application, agitation, settling, lime application, filtration, ozonation, aeration, and chlorination. Prior to installation of ozonators, finished water had unpleasant taste and odor and color of 25: now, taste and odor are eliminated and color ranges from 0 to 2. Ozonation adds about $.06 per 1,000 gallons finished water to the cost of electricity.—*Arthur P. Miller.*

Inadequate Facilities for Water and Sewerage Services in New Jersey. Anon. The American City, **50**: 12, 51, December, 1935. The New Jersey State Planning Board, through a staff of investigators, made a survey of the water and sewerage services of the state. In discussing water systems, report points out that 432 municipalities, comprising 94 percent of state's population, are served by one form or another of community water plant. About 68 percent of this service is publicly owned; the rest, privately. Only 100 incorporated munici-

palities with populations greater than 500 are lacking a community water supply. Of those served by supplies, about 2½ million people derive their water from surface sources; the rest, from wells. Wells predominate south of Trenton and for the sea coast communities south of Sandy Hook. Only 75 municipalities have water plants which provide fairly complete purification—*Arthur P. Miller.*

New Filters and Other Improvements in the Muskogee, Oklahoma, Water Works. Anon. The American City, **50**: 12, 59–60, December, 1935. Over a period of years, Muskogee has been improving its water supply system. As a P.W.A. project, a large settling tank has recently been gunited and converted into two three-million-gallon tanks and modern filtration plant has been constructed. With raw water turbidities running as high as 2500, filtration is essential for production of well clarified water. New plant includes six one-and-one-half-million gallon filter units and conforms to usual standards of design. Brief descriptions of pumping equipment, of Agency Hill Reservoir, and of other works are included.—*Arthur P. Miller.*

Water Supply as the Basis of Fire Protection. W. R. LaDue. The American City, **50**: 12, 47, December, 1935. Value of water supply in fire fighting is often overlooked because it involves no glamour. This article points out its importance and discusses its relation to fire insurance rates. Akron, Ohio, is stated to meet all requirements of National Board of Underwriters in so far as water supply is concerned.—*Arthur P. Miller.*

Pumping Costs Cut with Diesel. L. A. House. The American City, **50**: 12, 55, December, 1935. Gainesville, Texas, decided in 1933 to replace its steam pumping plant, taken over from private owners in 1911, with diesel equipment. Installation was completed in 1935; after 4 months of continuous operation, monthly saving in operating costs was shown to approximate $500.00. In addition, saving was made in cost of electricity for street lights.—*Arthur P. Miller.*

Faster Billing, Quicker Collections, Fewer Deadheads, Under New Regime in the Wheeling Water Department. J. B. Quinlan. The American City, **51**: 1, 71, January, 1936. Billing and collecting methods followed by Water Department in Wheeling are described. Evidencing effectiveness of revision of system, September 1935 showed an increase of about 180 percent in collections of delinquent accounts over September 1934. Collectors have been placed on a commission basis, in so far as delinquent accounts are concerned. One man has been appointed whose only duty is to shut off water from the premises of those refusing to pay their bills. Number of exempted water users has been cut from 1200 to 200 and able-bodied men who were willing to work were permitted to do so for the department, to pay their delinquent water bills.—*Arthur P. Miller.*

Shallow-Depth Elevated Tank Increases Pressure and Storage. Anon. The American City, **51**: 1, January, 1936. At Rocky Mount, N. C., there was

recently constructed, a million-dollar radial cone tank, 88 feet in diameter and 100 feet from ground level to bottom of tank. This tank will facilitate economical pumping, provide a greater volume of storage at a central point, and increase static head in distribution system. New tank was connected up with an old standpipe located in western part of city. In addition to these two elevated tanks, there are two ground level reservoirs at pumping plant with combined capacity of two million gallons. Rocky Mount is building also a new pumping station and filtration plant.—*Arthur P. Miller.*

Amebiasis in the Tropics and in North America. GEORGE C. BUNKER. The American City, **51**: 1, January, 1936. Following a brief description of general problem of amebiasis in Spanish America, author supplies information regarding its prevalence. In one native river village without sanitation, incidence was shown to be 72.7 percent; in another similar village, 33.0 percent. Among medical and surgical services in the Panama hospital, incidence was 19.1 percent and among the white staff of the Canal Zone Administration building, 2.81 percent. Incidence in Haiti was reported by WILLIAMS and THOMAS as 50 percent in 109 domestics and as 16.26 percent in 2,069 hospital patients by WILLIAMS, WILDMAN and CURTIS. De BALLARD reported an incidence of 30 percent in Venezuela in 1918. Although there is a difference of opinion regarding the extent to which amebic dysentery is transmitted by water in the tropics, author is of the opinion that water supplies, polluted as they frequently are in Spanish America, are equally important, as carriers with other agencies, and in some cases, more important.—*Arthur P. Miller.*

A Well-Operated Meter Shop. The American City, **51**: 1, 66, January, 1936. Discusses and describes the scheme in effect in Oklahoma City for routinal caring for and testing meters.—*Arthur P. Miller.*

Water Meters Reduce Costs by Stopping Rise in Water Consumption. Anon. The American City, **51**: 2, 58–60, February, 1936. Rapidly increasing consumption of water in Cali, Columbia, S. A., threatening to cripple the new and modern rapid sand filtration plant, was effectively checked by installation of meters. In 1927, consulting engineer for Cali had recommended universal metering, but it was not adopted until 1933. Normal capacity of the plant was 8 million gallons per day; but by 1932, maximum daily consumption had risen to 10.22 million gallons. It had become necessary each month to add from 3 to 9 percent of settled water to the filtered water to keep pace with the demand. In May 1935, with about 17.8 percent of services metered, addition of settled water was discontinued and in September, with 41 percent of services metered, average daily consumption had been reduced by 33 percent as compared with March. Metering in Cali has postponed indefinitely the need for additional filters; cut the cost of chemical treatment; increased the pressure in central section of the distribution system; permitted operation of the filters at their normal rate; and simplified other operation practices. The article discusses also the advantages and disadvantages of increasing the allowance of water per meter and points out that this figure must be very carefully considered for metering to result in reduction of waste.—*Arthur P. Miller.*

Treated Water Filtered in New Pressure Plant. DANIEL M. VAIL. The American City, **51**: 2, 65–67, February, 1936. At New Brunswick, New Jersey, it became necessary to supplement with additional facilities the old gravity water filtration plant. These include Dorr flocculator having detention period of 20 minutes; sedimentation basin having retention period of eight hours; and eight new pressure filters, each of 0.5 m.g.d. capacity; besides three new pumps. With chemical feed equipment available, ferric salt and lime may be applied at any one of five points.—*Arthur P. Miller.*

Meter Reading, Billing and Collecting Simplified. J. C. HOUSTON, JR. The American City, **51**: 3, 55–59, March, 1936. The Western New York Water Company serves the suburban area adjacent to Buffalo. Its supply comes from Lake Erie and is filtered before distribution. Services are 100 percent metered and there are 12½ thousand active accounts, all but 100 of which are either domestic, or small commercial, consumers. System in use for meter reading and checking, billing, and collecting is thoroughly described.—*Arthur P. Miller.*

A Village Water Supply in Rip Van Winkle Country. Anon. The American City, **51**: 3, 73–74, March 1936. Catskill, New York, a village of approximately 5,000 persons, secures its drinking water from impounding reservoir about 10 miles to the north-west, collecting from 19 square miles of drainage area. Purification processes include coagulation with alum, aëration through spray nozzles, settling for detention period of about four days, and rapid sand filtration. A feature of the plant is its small number of valves and of valve types. One single hydraulically operated influent valve controls flow of water to all six filters. Each filter has a single-lever-operated, quick-opening wash-water valve, and there is but one main effluent valve and one main sewer valve for all six filters. This combination of valves necessitates shutting down of plant to wash a single filter. To protect against loss of sand by too rapid washing, five small porcelain cups are securely wired to a pole with the top of the first cup six inches from the end of the stick and the top of each successive cup 3 inches higher. This stick is held at a definite elevation during washing and by frequently removing it, the elevation to which the sand is lifted during washing can be determined. Sand lift is maintained at about 12 inches, leaving an ample factor of safety against sand loss, because wash water troughs are 24 inches above normal sand elevation.—*Arthur P. Miller.*

America's Oldest Filtration Plant. Anon. The American City, **51**: 4, 46–48, April 1936. KIRKWOOD, the first water filtration engineer in the United States, designed and supervised construction and operation of the first slow sand filtration plant in this country, at Poughkeepsie, in 1872. The same filters are still in operation; but others have been added and further improvements made. Hudson River water flows from intake by gravity to the pumping station, where anhydrous ammonia is applied in first pump well and chlorine in the second. Ratio is one part of ammonia to three of chlorine. Low-lift pumps draw from second well, alum being added at the suction, and deliver to sedimentation basin with twelve-hour normal detention period: activated

carbon, added at inlet, effects a saving in coagulant. After settling and preliminary filtration through rapid sand filters, water is aërated and flows by gravity to slow sand filters. Lime is added to effluent from two of the slow sand filters which is then mixed with the rest of the water in the clear well. Distribution follows.—*Arthur P. Miller.*

New Semi-Automatic Filtration Plant at Christopher, Illinois. JAMES GRATTAN COONEY. The American City, **51**: 4, 57–58, April, 1936. With aid of loan and grant from P. W. A., Christopher, Illinois, a town of 7,000 persons, was able to transform its original water purification system, consisting only of chlorination, into a modern one. New plant includes mixing chambers, settling basin, aërator, filters, and clear well. Mixing chambers may be operated in parallel or in series, and are equipped for mechanical mixing. Laboratory and other control devices have been installed and space for chemical storage has been provided. By a system of float valves, plant is made semi-automatic. —*Arthur P. Miller.*

The Industrial Waste Situation. Anon. The American City, **51**: 4, 60–61, April, 1936. Short tabular summary lists types of industries active in studying treatment of industrial wastes and shows in which states this work is being carried on. Industrial waste disposal methods may be classified as (*a*) those which involve reprocessing and salvaging material within the plant, and (*b*) those which simply dispose of waste in the least harmful or costly manner. Profitable recovery should be the first objective in any waste-disposal program. Incomplete reports show 523 industrial waste disposal plants in 23 states. Investment in these plants, designed to prevent water pollution, is estimated as 22 million dollars. This figure does not include the cost of mine sealing operations. None of the 29 reporting states indicated a strictly official cooperation between industry and state representatives, although in several of them unofficial relationships are maintained. Specific reasons for lack of industrial waste treatment plants are given. Emphasis is placed upon the fact that disposal of each waste must be considered as a separate problem.—*Arthur P. Miller.*

Second Large Elevated Tank Balances the Evanston Water System. Anon. The American City, **51**: 4, 63–64, April, 1936. In 1935 Evanston, Illinois, completed the installation of elevated tank having capacity of one million gallons. In 1932, one half again as large had been built. Both tanks are of same design, incorporating modern architectural treatment. Water level in tanks is regulated by remote control from pumping station and filtration plant. Fire flow tests reveal considerable increase in capacity to meet heavy drafts for fire fighting, because of second tank.—*Arthur P. Miller.*

Birmingham's Industrial Water Supply. Anon. The American City, **51**: 5, 66, May, 1936. As a joint P. W. A.-W. P. A. undertaking, Birmingham, Alabama, is to have a new six million dollar industrial water system. Although this city has adequate good water for domestic use, it has always been handicapped by insufficient cheap industrial water, which has hampered its

industrial growth. Under the joint arrangement, W. P. A. will undertake to clear the site and excavate for the impounding dam; to clear the reservoir site; and to relocate certain roads. P. W. A. will build the dam and a portion of the water line and then W. P. A. will finish the distribution reservoir and lines. Capacity of main reservoir behind the dam will be sufficient to supply 60 million gallons of water daily.—*Arthur P. Miller.*

New Deferrization Plant at Reading, Massachusetts. PHILIP WELCH. The American City, 51: 5, 72–73, May, 1936. In water supply at Reading, Mass., inaugurated in 1931, sufficient iron developed within four years to give rise to complaints. Deferrization plant has therefore been installed, in which water is aërated by spraying through nozzles on to coke beds and then filtered through slow sand filters. The pumping plant being automatic, this new iron removal unit has also been made automatic.—*Arthur P. Miller.*

Fast Billing at Brainerd, Minn. W. D. MCKAY. The American City, 51: 5, 77–80, May, 1936. Description of new meter reading and billing scheme placed in effect in Brainerd, Minn.—*Arthur P. Miller.*

Corrosion of Copper. GLENN H. DAMON and RAY C. CROSS. Ind. Eng. Chem., 28: 2, 251–3, 1936. At all concentrations up to about 25 normal, above which oxidizing character of acid intervenes, corrosion rate in sulfuric acid solutions is directly proportional to oxygen solubility. Maximum corrosion rate is at 0.2 normality. Rate of oxygen diffusion through air-liquid interface controls corrosion rate unless solution surface area is very large in comparison to metal surface area. Standard corrosion test methods must specify solution surface area. Same factors as for copper should control corrosion rate for all metals whose corrosion depends on oxygen depolarization.—*Selma Gottlieb.*

Reaction between Paint Films and Zinc Surfaces. HENRY J. WING. Ind. Eng. Chem., 28: 2, 242–3, 1936. Failure of paints to adhere properly to zinc or galvanized surfaces may be due to reaction between zinc and oxidation products formed in drying of oil or varnish type finishes. Zinc formate has been identified as one product both in laboratory experiments and in examination of paint films peeled from galvanized surfaces.—*Selma Gottlieb.*

Direct Titration of Sulfates. R. T. SHEEN and H. L. KAHLER. Ind. Eng. Chem., Anal Ed., 8: 2, 127–30, 1936. The SCHROEDER method, using tetrahydroxyquinone as internal indicator, has been applied to sulfate concentrations up to 30,000 p.p.m. by use of sodium chloride to sharpen end-point above 2000 p.p.m. of sulfate, and increased amounts of indicator at high concentrations. Up to 60 p.p.m., phosphate interference can be eliminated by pH control. Isopropyl alcohol can be used instead of ethyl alcohol. Results checked gravimetric analyses within 3 percent average and gave fairly good agreement with BETZ-HELLIGE method.—*Selma Gottlieb.*

Determination of Sulfate. JOHN E. RICCI. Ind. Eng. Chem., Anal. Ed., 8: 2, 130–1, 1936. By direct titration with 0.1 molar lead nitrate solution using

12 drops of 0.5 percent eosin as indicator, 0.1 to 0.25 gram of sodium sulfate can be determined in total final volume of 30 to 40 cc. With 0.15 to 0.20 gram of sodium sulfate, determination is accurate to 0.0005 gram of compound. One gram of alkali nitrate or two grams of alkali chlorate does not interfere.—*Selma Gottlieb.*

Determination of Iron in Sea Water. NORRIS W. RAKESTRAW, HENRY E. MAHNCKE, and ELIOT F. BEACH. Ind. Eng. Chem., Anal. Ed., **8**: 2, 136–8, 1936. Soluble iron was precipitated in filtered sample as ferrous sulfide, followed by solution in hydrochloric acid. Color obtained on treatment with potassium thiocyanate in presence of ethylene glycol monobutyl ether was compared with standards. Concentration of soluble iron was seldom over 10 mg. per cubic meter in sea water of Woods Hole, Mass., area.—*Selma Gottlieb.*

Improved Apparatus for Isolation of Fluorine. W. K. GILKEY, H. L. ROHS, and H. V. HANSEN. Ind. Eng. Chem., Anal. Ed., **8**: 2, 150–1, 1936. Distillation of hydrofluosilicic acid by WILLARD and WINTER method is simplified by using steam distillation instead of intermittent addition of water to distillation flask. Both distillation flask and steam coil are kept at proper temperature by immersion in vapor of boiling tetrachloroethane (145°C.). Sulfuric acid is used instead of perchloric.—*Selma Gottlieb.*

Soluble Silicate Cleansers. JAMES G. VAIL. Ind. Eng. Chem., **28**: 3, 294–9, 1936. Silicate cleansers exhibit properties not always attributable to their alkalinity, but due, instead, to silica content. They are less corrosive to soft metals such as tin and aluminum than are other common alkalies, increase bactericidal effect of sodium hydroxide, assist deflocculation and prevent redeposition of dirt in laundering, are useful in cleansing containers because of good wetting power against oils, glass, and metals, and contribute valuable properties to soap when used as builders. Compounds of various sodium oxide:silica ratios are adapted to various uses.—*Selma Gottlieb.*

Evaporation from Free Water Surfaces. M. LURIE and N. MICHAILOFF. Ind. Eng. Chem. **28**: 3, 345–9, 1936. Using data from 88 laboratory experiments, empirical formula is deduced, which is valid for conditions studied (40° to 225°C. and air velocities from 1 to 7.5 meters per second). Rate of evaporation is proportional to difference between partial pressure of water vapor in air and vapor pressure of water at temperature of liquid evaporated, and is linear function of air velocity.—*Selma Gottlieb.*

Coal Ash and Coal Mineral Matter. G. THIESSEN, C. G. BALL and P. E. GROTTS. Ind. Eng. Chem., **28**: 3, 355–61, 1936. Examination of numerous coal ash analyses indicates that 95 percent of coal ash is composed of oxides of aluminum, silicon, calcium, and iron. Petrographic examination of separable mineral matter from Illinois and Western Pennsylvania coal shows 95 percent detrital clay, kaolinite, calcite, and pyrite. Clinker formation is influenced by mode of occurrence and distribution of portion of ash having lowest softening temperature, and is increased by localized concentrations of more readily

fusible material. Accelerating effect of pyrites is due to iron oxide formed on combustion and not to properties of molten ferrous sulfide. Methods for estimating ash softening temperatures (from phase diagram) are useful if ash analyses are available; but rapid ash analysis method is needed. Ash softening temperatures are function of composition in terms of above four oxides.—*Selma Gottlieb.*

Magnesium Compounds from Ocean Water. H. HENRY CHESNY. Ind. Eng. Chem., **28**: 4, 383–90, 1936. Sea water is chlorinated, treated with enough lime to precipitate calcium carbonate, settled and filtered. Magnesium hydroxide is precipitated from filtrate with lime slurry, settled, washed, filtered in some cases, and worked into various desired products. Details and economics of process are discussed.—*Selma Gottlieb.*

Bituminous Plastics. R. N. TRAXLER. Ind. Eng. Chem., Anal. Ed., **8**: 3, 185–8, 1936. Flow properties of bituminous plastics were studied by parallel-plate plastometer, Baldwin-Southwark compression testing machine, alternating stress method of BINGHAM and STEPHENS, and coaxial cylinder viscometer. No one method satisfactorily evaluates complicated flow properties encountered, but such studies give needed approach to understanding of behavior of bituminous plastics in use. Testing of filled bitumens, paving mixtures, roofing asphalts, and flooring materials by these methods and others is discussed.—*Selma Gottlieb.*

Volumetric Determination of Sulfate in Water. MAGARET D. FOSTER. Ind. Eng. Chem., Anal. Ed., **8**: 3, 195–6, 1936. Sulfate is precipitated with standard solution of barium chromate in hydrochloric acid, and excess barium chromate is precipitated with ammonium hydroxide. Chromate equivalent of sulfate precipitated is determined iodometrically in filtrate, calculation being made with reference to blank. On 100 water samples, containing 2 to 1786 p.p.m. of sulfate, results checked gravimetric determinations within ±0.2 mg. Possible interfering substances are present in only negligible amounts in ordinary natural or boiler waters.—*Selma Gottlieb.*

A New Reagent for Potassium. I. Qualitative. A. W. CLARK and C. O. WILLITS. Ind. Eng. Chem., Anal. Ed., **8**: 3, 209–10, 1936. Three ml. of naphthol yellow S solution in 10 ml. of test solution will detect one part of potassium in 2500 parts of solution. Sodium does not interfere but delays appearance of precipitate. Ammonium, lithium, and magnesium do not interfere.—*Selma Gottlieb.*

Action of 4-Nitrocatechol as a Titration Indicator. S. R. COOPER and V. J. TULANE. Ind. Eng. Chem., Anal. End., **8**: 3, 210–11, 1936. One per cent aqueous solution of 4-nitrocatechol was used as indicator in titration of nitric acid with sodium hydroxide and of hydrochloric acid with sodium hydroxide, ammonium hydroxide, and sodium carbonate. Action of indicator is affected by carbon dioxide; but it is not oxidized by nitric acid. Change from straw color to red is between pH 3.92 and 10.57 and from straw color to lemon yellow between pH 3.92 and 6.34 at 25°C.—*Selma Gottlieb.*

Determination of Small Amounts of Potassium by Means of Silver Cobaltinitrite. REX J. ROBINSON and GARTH L. PUTNAM. Ind. Eng. Chem., Anal. Ed., **8**: 3, 211–13, 1936. BEER's law is valid over wide range in GRIESS method for nitrite, if 10 per cent acetic acid medium is used. Accuracy is improved by mixing reagents before use. By precipitating from 30 volume-percent alcohol medium at 4° to 6°C., 0.003 mg. of potassium per ml. of solution may be determined with sodium cobaltinitrite. Using silver cobaltinitrite and running potassium standards simultaneously, 0.002 mg. of potassium may be determined. Precipitation is done near 0°C., and acetone solution is used in washing. Method is applicable to determination of potassium in fresh water. —*Selma Gottlieb.*

Borax as an Acidimetric Standard. FRANK H. HURLEY, JR. Ind. Eng. Chem., Anal. Ed., **8**: 3, 220–1, 1936. Recrystallized borax dried with alcohol and ether, or in desiccator over saturated sugar-salt solution, gave results agreeing with sodium carbonate when titrated against hydrochloric acid, using methyl red indicator. Borax dried with alcohol and ether may be exposed to atmosphere under ordinary conditions for ten days without causing significant error.—*Selma Gottlieb.*

New Apparatus for Analytical Laboratories. F. E. TUTTLE. Ind. Eng. Chem., Anal. Ed., **8**: 3, 230–1, 1936. Nickel wire crucible support for desiccators, short, wide graduated cylinder with two lips and cover for Erlenmeyer flasks are described.—*Selma Gottlieb.*